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EIGHTH ANNUAL ASPHALT PAVING CONFERENCE - 1929

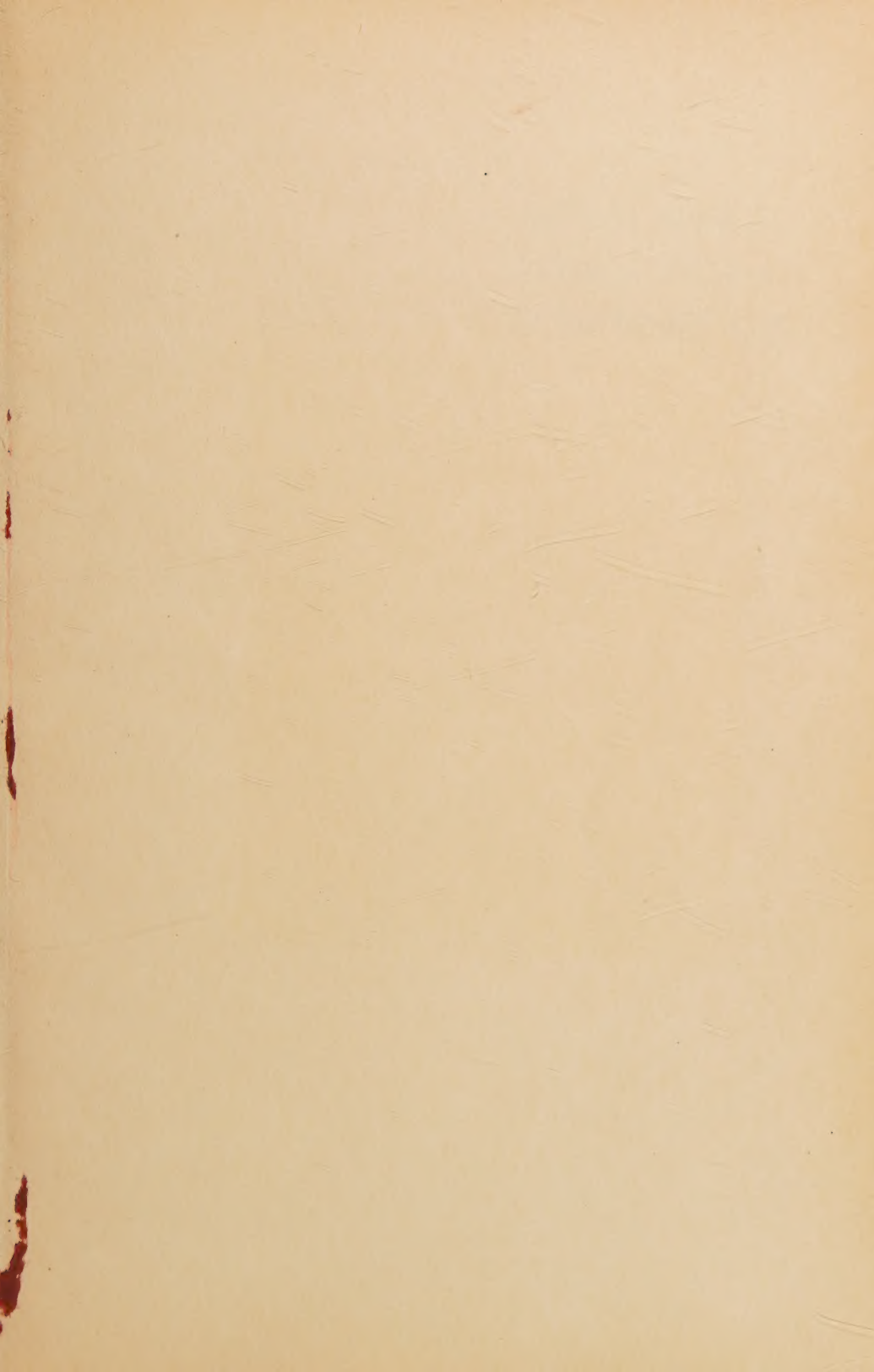
**AIRPORTS - LOW COST ROADS - "BLACK BASE"
WATERPROOFING SUBGRADES
RESURFACING CONCRETE ROADS
MACHINE - FINISHING ASPHALT PAVEMENTS**

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EIGHTH ANNUAL
ASPHALT PAVING
CONFERENCE 1929



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EIGHTH ANNUAL ASPHALT PAVING CONFERENCE

[Proceedings]

Held Under the Auspices of

THE ASPHALT ASSOCIATION

and

THE ASSOCIATION OF
ASPHALT PAVING TECHNOLOGISTS



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FOREWORD

Approximately five hundred highway engineers, public officials, asphalt producers, salesmen, chemists and others interested in the development of asphalt paving both for highways and airports attended the sessions of the Eighth Annual Asphalt Paving Conference at West Baden Springs, Ind., Oct. 28 to Nov. 1, 1929. The actual registration of 457 equalled the registration at the Sixth Annual Asphalt Paving Conference, Atlanta, Ga., in 1927. From forty to fifty persons were present who did not register.

The program was presented in five sessions, of which two were devoted to research, two to the engineering and economic phases of asphalt construction and one to airports. The research sessions were held in conjunction with the Association of Asphalt Paving Technologists and the others were under the direction of the Asphalt Association.

The entertainment features were unique and highly enjoyable. Never have the delegates to an asphalt paving conference received a more cordial and enjoyable welcome than did those who were present at West Baden. The social events included an "informal open house," reception and concert, dance, "county fair and carnival," a luncheon and bridge party for the ladies and a golf tournament for the men.

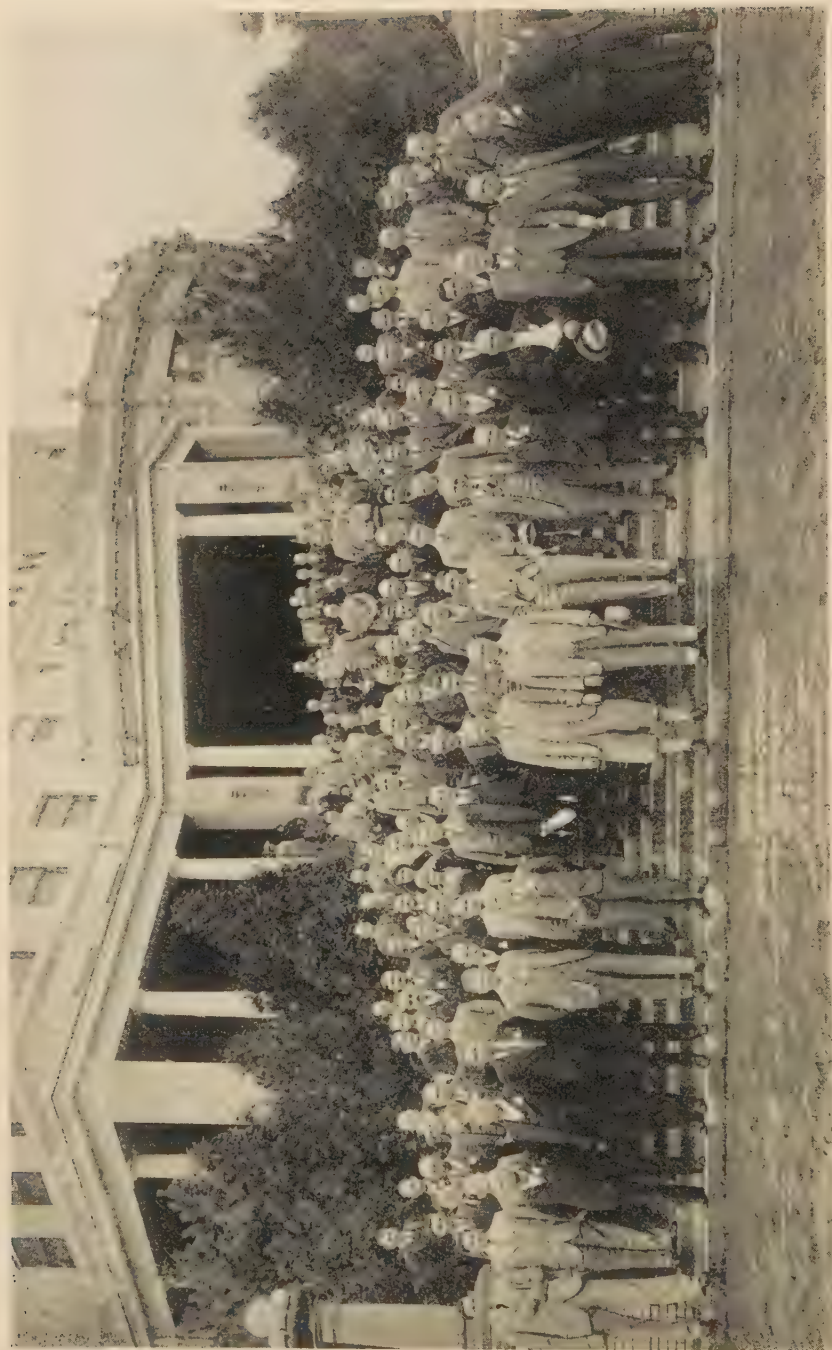
A roster of the presiding officers who so ably guided the proceedings throughout the several sessions is as follows: First Session, Leroy M. Law, President, The Asphalt Association, Second Session, Hon. A. J. Wedeking, Chairman, Indiana Highway Commission; Third Session, Hon. R. M. Smith, Deputy Minister of Highways, Ontario Province, Canada; Fourth Session, W. J. Emmons, President, Association of Asphalt Paving Technologists; Fifth Session, Major Frank M. Kennedy, Chief, Buildings & Grounds Division, Office, Chief of Air Corps, U. S. Army.



LEROY M. LAW
PRESIDENT, THE ASPHALT ASSOCIATION,
1929



PREVOST HUBBARD
PRESIDENT, ASSOCIATION OF ASPHALT PAVING TECHNOLOGISTS,
1930



GROUP OF DELEGATES ATTENDING EIGHTH ANNUAL ASPHALT PAVING CONFERENCE

Eighth Annual Asphalt Paving Conference

West Baden Springs, Ind., Oct. 28-Nov. 1, 1929

OPENING SESSION

WEST BADEN SPRINGS HOTEL, 10 A. M., OCT. 29, 1929,
LEROY M. LAW, PRESIDENT, THE ASPHALT ASSOCIATION, PRESIDING

President Leroy M. Law of the Asphalt Association called the conference to order and read his annual address, which was followed by the address of Mr. W. J. Emmons, president of the Association of Asphalt Paving Technologists.

President's Annual Address

By Leroy M. Law, St. Louis, Mo.

President of The Asphalt Association

The presence of so many of you here today is, indeed, a substantial tribute to the usefulness of these asphalt paving conferences. Looking back to the summer of 1922, at least some of you will recall the rather informal gathering in which this institution had its origin. Although the World War had been over for several years, many of the obstacles unavoidably imposed on industry by the great conflict still remained to embarrass the resumption of highway activities. Accordingly, about two hundred state and municipal officials, engineers, chemists and representatives of asphalt producers met in Atlanta to exchange views as to the best methods for improving the situation. Although sponsored by the Asphalt Association, then in the early years of its activities, the meeting was far from that of a trade organization seeking primarily to promote the sale of its product. On the contrary, it was truly a "conference" and, once this designation had been applied, it has seemed to be regarded as more and more appropriate by those who participated in the original and subsequent sessions.

The results at Atlanta far exceeded the expectations of our most hopeful participants and, before a year had elapsed, it was decided to hold another similar session. This was held at Denver, Colorado, with a gratifying attendance, double that of the meeting at Atlanta. The same conference idea prevailed and there was, in addition, a more elaborate program of papers dealing with asphalt construction. This conference was unique in that it included engineers representing most of the states between the Atlantic and Pacific. By this time an annual paving conference came to be regarded as a more or less permanent fixture in the paving industry and, as you know, there followed the conferences at Louisville in 1924 and Detroit in 1925. The 1926 session in Washington, held jointly with the American Society for Municipal Improvements, deserves especial recollection. Next came a repeat visit to Atlanta in 1927.

I am sure that most of you were present at the New Orleans session last year.

And so it becomes my privilege to open this, our Eighth Annual Asphalt Paving Conference; and, in doing so, let me express the hope of its sponsors that you will find it a helpful one. We are retaining the conference idea of the original meeting, seeking to find out how we can continue to improve the asphaltic types of paving and road building by eliciting suggestions from representatives of all phases of the industry. In this connection we have especially sought the views of Federal, state and municipal officials who are charged with the road building responsibilities in the interest of the taxpayers and we have, indeed, been gratified at their ready response in connection with the preparation of our programs.

MEETING OF ASPHALT TECHNOLOGISTS

Meeting with us this year, as was the case of the two previous sessions, we have the Association of Asphalt Paving Technologists. This organization of scientific men has for its purpose the advancement of the technology of asphalt paving construction. By the encouragement of a closer contact between technologists responsible for paving work and, through the coordination of asphalt paving research, they aim to be of greatest usefulness to the industry of which they constitute an important factor. Their own president soon is to address you, however, and he will tell you more as to what his organization is doing.

We have with us, also, representatives of the American Farm Bureau Federation, an organization which, for nearly ten years, has been championing the cause of farm relief. They tell us that nearly 5,000,000 farmers still live on dirt roads and point out the injustice of a situation in which the farmers of the United States pay 7 per cent of the taxes for state and local highways, yet less than 3 per cent of them can be reached by paved highways. It goes without saying that a message from the Farm Bureau Federation as to remedying such conditions should be of special interest to this conference.

BRIGHT FUTURE FOR ASPHALT INDUSTRY

It seems to me that our industry is at the doorway of a bright future for, not only can we continue to supply the higher types of pavement already recognized as standards by so many of our city and state engineers, but even greater opportunities offer themselves in other directions. For example, Mr. E. W. James of the Bureau of Public Roads in his able paper presented last year at New Orleans told us that there were approximately 1,822,867 miles of roads in this country that were still wholly unimproved. Furthermore, he reported that, of the total improved roads, amounting to 1,177,324 miles, 1,000,000 miles, or 88 per cent, were of types inferior to water-bound macadam. These consist of roads merely drained and graded and roads with such primitive surfaces as top-soil, sand-clay and gravel. It has been the inability of our rural population to get out during all the year over such roads and so reach the main arteries that has given rise to a strong public sentiment for their improvement. In view of the great mileage involved and the demand for early relief, there has arisen the problem of providing satisfactory low

cost roads for this secondary highway system. I am sure that the totals have not been reduced appreciably since we met last December, and asphalt, by reason of its diversity of application, should hold a unique position in such a potential program.

Nor do we need be concerned only with highways for terrestrial traffic for nowadays traffic of the air offers us new opportunities. Modern airplanes are daily becoming more and more a factor in our transportation system and these powerful, yet delicate, vehicles require smooth and resilient surfaces on which to begin and end their flights. Indeed, the establishment of several commercial airways operating on regular schedules has already necessitated the building of numerous airports and we are told that a total of 1700 are now already in contemplation. Yardages involved in the paving of airports are, necessarily, large ones so that the economy offered by the use of the asphaltic types will doubtless be an important factor in the selection of pavements for these institutions.

With these potential opportunities, certainly the outlook is extremely encouraging. Opportunities, however, must be developed before results can be expected and, at this time, what we need is cooperation in development as well as development by individuals. Already, it seems to me that much has been done by individual efforts, especially in the field of low cost roads and surface treatments. Should we not, therefore, face these future prospects from the viewpoint of an industry, take stock of the information already at hand and endeavor to separate the essential facts from the non-essentials. Certainly by doing so we shall be able to give to the future road builders some basic principles rather than a confusion of individual experiences. After all, the future of the industry will be what we of the industry make it.

ASPHALT ASSOCIATION REORGANIZED

I feel quite sure that our Asphalt Association has been endeavoring to meet those responsibilities which properly will come to it during the coming developments in the industry. It has, in fact, during the past year undergone a complete reorganization so that today it is more representative of the industry than ever before. It has been actively in cooperation with the Federal Bureau of Public Roads in reference to the simplification of specifications for surface treatments and the more important investigation of satisfactory types of low cost road surfaces previously referred to. As our sessions proceed you will learn from able speakers what has been done along these lines.

My function here this morning is to set in motion the machinery of another asphalt paving conference. In doing so, let me thank, in behalf of the sponsors, firstly, those officials, engineers and other experts in their line who are contributing so liberally of their time and experience to the programs of these sessions; secondly, those of you who by your very presence here give encouragement to our efforts. We are glad to hold this conference in Indiana, a state whose engineers are regarded as leaders in asphalt road construction. All of you have heard of their retread pavements and, during the course of our sessions, we shall doubtless be able to profit much from their practices and experience. Finally, a word of appreciation to the West Baden Springs Hotel whose manage-

ment is looking after our personal needs and comforts so that our stay here may be a pleasant one.

The Eighth Annual Paving Conference is now formally open and you will next hear from the president of the Association of Asphalt Paving Technologists, Mr. Walter S. Emmons.

Address of W. J. Emmons Ann Arbor, Mich.

President, Association of Asphalt Paving Technologists

At this, the annual joint meeting of the Asphalt Paving Conference and the Association of Asphalt Paving Technologists, it is well to take an inventory of our position in the field of highway activities,—our accomplishments, our opportunities and our needs. Stated concisely, the paving conference records the progress of the art of asphaltic construction; the Association of Asphalt Paving Technologists attempts to stimulate the study of paving problems and to disseminate knowledge obtained from such studies.

The conference is fulfilling its function well, and has attained a position as one of the really important yearly technical meetings. The Association of Asphalt Paving Technologists, as an organization, is not so far advanced that it may point to any considerable record of accomplishment. It is with the hope of stimulating interest in its ambitions, of emphasizing the importance of its activities to the whole industry, and of gaining more practical support in its promotion of research that these words are addressed to you.

There still persists a tendency to regard research as something vague, mysterious, impractical and remote from the problems of execution. Research may be just that in some sciences, but even so, after reviewing the advances of the past century, no one would dare deny the potential value of such activities. In our own field, however, there is little danger of the dissipation of energy in purely abstract research. The spirit of the times demands physical accomplishment, and the problems encountered are far too pressing. In fact, if this great and insistent movement for more and better highways has an unfortunate side, it is manifested by the inclination to overlook the necessity for a careful detailed study of engineering fundamentals.

VALUE OF RESEARCH UNDERESTIMATED

I regard the present status of research as relatively unsatisfactory. The Federal Government is accomplishing a great deal. The states, counties and cities are active to a greater or lesser degree, as are also the universities and colleges. Certain trade associations have established notable laboratories and individual companies have done likewise in some instances, especially in the field of promotional research. Taken by and large, however, the potential value of research is underestimated, and, consequently, its conduct is not regarded as a major activity. It is looked upon as a luxury rather than the prerequisite to progress. Many delve

into research enthusiastically, although necessarily superficially, during those seasons when construction is suspended, but its continuous, persistent prosecution, as a necessary adjunct to the business of building better roads, is left to the conspicuous few.

Our own committees of the Association of Asphalt Paving Technologists, made up of men of outstanding prominence in the highway industries, are less active than they should be, due to this handicap. The machinery for planning, coordinating and disseminating research is in good working order. It is the facilities for conducting really extensive research which are not functioning properly.

It is true that there is no overwhelming popular demand for research in highways, as there is, for instance, in the field of medicine. Perhaps we ourselves have been somewhat to blame for this condition. Are we altogether frank in our relations with the public? Do we admit that there are problems in connection with the design and construction of modern highways for which we do not know the answers, but which, if solved, would give greater value to the taxpayer's dollar? The people should know that the demands which they so insistently make for better highway facilities cannot be met by adherence to inherited practices. New types must be developed and older types more thoroughly understood before cheaper and better highways can be constructed. The manner of using highways has changed and our own success in meeting new conditions must be predicated upon a sound appraisal of their significance. The records of successfully completed investigations clearly demonstrate that the most rapid and, in the long run, the most economical manner of accomplishing these ends, is through the medium of systematically organized and correlated research.

GREATER RESEARCH ACTIVITIES URGED

I would not have every organization engaged in highway activities establish an elaborate research laboratory. I would, however, have every organization interested make a real effort to participate actively, to the greatest possible extent. Whenever feasible, one or more men should be assigned to research work, with no other interest than to study, thoroughly and exhaustively, problems of local interest, to know what is being done elsewhere and to work in conjunction with others interested in the same subject. I would urge greater support and encouragement of those organizations which, at present, sponsor and conduct research on a larger scale. I would encourage the establishment of research foundations at well equipped universities and colleges. Last, and as important as any, I would give greater publicity to the needs for and the benefits of research. Such a policy would, I am sure, guarantee dividends in economy, better quality and greater public satisfaction.

Despite the prevailing unorganized conditions, the picture of research is not altogether a gloomy one. Much has been and is being accomplished. Progress is, however, unnecessarily slow, due, I am sure, to a lack of appreciation on the part of those who control expenditures of the really golden opportunity which is open.

Surely there can be no disagreement in these matters on the part of those who are active participants in this great movement for better high-

ways. The need is present, the benefits are virtually certain. Why not, then, spend a really appreciable fraction of our funds for research, so that the remainder, the vast bulk, will be more advantageously expended? In the haste to get things done, let us not neglect to learn how to do them better.

PRESIDENT LEROY M. LAW: A few moments ago I stated that we hope to learn more as to what Indiana has been doing in the way of road building, and had hoped to have with us on this occasion the Governor of the State. Unfortunately he is unable to be with us, but we are fortunate in having with us a gentleman who is most actively identified with the highway interests of the state, Mr. John J. Brown, director of the Indiana State Highway Department, who will now talk to us.

Address of Welcome

By John J. Brown, Indianapolis, Ind.

Director, Indiana State Highway Department

It affords me real pleasure to come into this presence, first of all to extend to you a sincere welcome to Indiana. I very much regret the inability of the Governor to be present upon this occasion, and he commissioned me to say to you that he sincerely hoped that this meeting would be profitable as well as pleasurable to all of us. He requested that I extend to you his regrets on account of his inability, because of other duties devolving upon him, to attend this meeting.

It will not be my purpose to take much of your time, but there are just a few little things that I desire especially to call to your attention,—particularly to the attention of those who are residents of Indiana. The greatest need of this hour in Indiana, in my opinion, is some sort of more workable and more intelligent regulatory statutes controlling the highways in the state. It may be interesting to all of you to know that in our state system we have approximately 5000 miles of highways, about equally divided between the macadam type of road, or the secondary type of road, and the more permanently constructed highway. During this present year, it may be interesting to you to know, we will have finished approximately 532 miles of the more permanently constructed highways. During this same year we have treated with the dustless treatment approximately 660 miles of our highways, and we found that the people have been duly appreciative and grateful. I do not know what the experience is in other states, but we are in a fog of dust over many of our highways and appeals are being made from every section of our state to do something to rid the people of this fog of dust that is almost suffocating in its consequences.

INDIANA DEVELOPING GREATER EFFICIENCY

The Governor requested that I say to you that it was a source of great gratification to him that men of the type of many of you in this presence

are taking such an intense and conspicuous interest in the problem of more and better highways. He believes that on account of the type of men who are interested in this work, we will raise to a higher level the standard of efficiency. One of the things which we are making an earnest effort to accomplish in our highway department is to raise our standard of efficiency to the same level as that of the most successful private institutions. In other words, we are attempting to employ the same standards of efficiency in the administration of our state government that you men employ in the administration of your own most important affairs.

Now, gentlemen, the great need of Indiana today, as I have said to you in a word, is more workable and efficient statutes and better control. One of the things with which we are confronted in Indiana is that our roads are being subjected to a weight by trucks and various other transportation facilities, that they were never intended to carry. That is one of the things. Another thing is the speed at which people are inclined to operate their automobiles—dangerous in the extreme, in my humble judgment. We may keep up this program of unlimited speed, as we have it in Indiana, because we have no limit over here, and you can take off the lid and drive as fast as you like and there is no one who can gainsay, but I am saying that we are having a period of human slaughter, that, to my way of thinking, is indefensible and inimical to the progress of our state, and dangerous to those who want to operate their cars intelligently and with safety and who want to take their families out for a ride and enjoy the pleasure of automobiling. There are many things I could stand here and call your attention to that Indiana is in need of. I am not saying that speed control and weight control of vehicles on our highways are the only things, but those are some of the outstanding needs of our state.

THE GLORIES OF INDIANA

I am not going to take up more of your time. You have other speakers here who can talk to you much more intelligently, from a technical standpoint, than I can. They can give you information you are seeking, but before I sit down, I desire to pay to the State of Indiana just one little tribute in the further extension of your welcome. Gentlemen, again I welcome you to Indiana—the state where the handclasp is just a little stronger, where the smile dwells just a little longer, where the sun is just a little brighter, where the bonds of love are just a little tighter, and life's burdens are just a little lighter. Gentlemen, that is Indiana. Again I welcome you—where the skies seem just a little bluer, where friendship and affection are just a little truer, where there's fragrance in every breeze that's blowing, where there's laughter in every stream that's flowing; that is Indiana. Gentlemen, again I welcome you. It is here where the blending of beauty is always in the making, where fewer hearts with despair are aching, where there's more of singing and less of sighing, where there's more of giving and less of buying, and you can make friends over here in Indiana without half trying; yes, gentlemen, I welcome you. It's here in Indiana where nature has done so much in demonstration of her artistic touch. Of it all we invite you to partake

most generously for Indiana's sake, and gentlemen, again I extend to you, with sincerest cordiality, a welcome to our hospitality. I thank you.

PRESIDENT LAW: We have with us this morning a gentleman who, for some time, has occupied a position of national importance and who perhaps does not require any introduction. He represents a great organization which is working in behalf of the American farmer, and he is going to talk to you on this all important subject of low cost roads. It is with great pleasure that I introduce to you Mr. S. H. Thompson, president of the American Farm Bureau Federation.

Low Cost, Paved Farm-to-Market Roads— A National Economic Necessity

Address by Sam H. Thompson, Chicago, Ill.

President, American Farm Bureau Federation



SAM H. THOMPSON
PRESIDENT AMERICAN FARM
BUREAU FEDERATION

I assure you it affords me a real pleasure to attend your meeting and to have an opportunity to give you some of the practical thoughts of one who represents the farmers of America, based on my own practical experience and the need of the farming industry.

In dealing with any economic problem, it is natural for the individual to think of that problem, first of all, as it affects him as an individual, as it affects his family and his own community. In talking to you this morning about farm-to-market roads as a national economic necessity, I should like, first of all, to think of farm-to-market roads as a necessity in my own state—Illinois. I should even like to think first of roads in my own county—Adams County—as they apply to one of my own farms.

In Adams County, over on the Mississippi River, I have a farm that is not on a year-round road. My farm is not unique. There are many others in that county that do not enjoy roads that can be used the year round. A short time ago the farmers in that community got together with the county and worked out a system for getting a partial secondary road system. This was done by the farmers themselves contributing jointly with the county the funds from which these secondary roads were built. I contributed my share as agreed upon

for every acre in this farm of which I spoke. The money was used in building some secondary roads but the nearest road to my farm is one mile away. On an average three months out of the year that road isn't worth a nickel to me because I cannot reach it from my farm. The intervening mile of mud makes it impossible.

That mile of mud is costing me money. It is not only costing me money but it is costing the merchants of the community, it is costing the railroads, it is affecting in its small measure our entire economic structure. Let me illustrate. Ten days ago I paid 25 cents a ton-mile to move 60 tons of limestone six miles from the railroad to this farm. In other words, it cost me \$1.50 a ton, or \$90 to move the entire amount. This limestone cost me \$2.10 a ton laid down at the railroad.

You men are interested in building roads but I do not feel that I am becoming too technical when I mention the need of limestone in Illinois if we are to maintain the proper condition of our soils. I must confess that with all the information I have as to the added fertility, this 60 tons of limestone would give my farm, I had to stop and think twice before I could pay the \$90 hauling charge. Now if we had had a year-round road to our farm, this limestone would have been moved during the winter by the men on the farm in our own trucks when trucks and men were idle. There would have been no particular cost other than the regular overhead of the farm. As it was, we were forced to move it hurriedly at a time when the dirt roads were dry and hard.

NEED OF YEAR-ROUND PAVED ROADS

In that one illustration of something that occurred in my own farming experience within the past two weeks you have a picture which portrays the whole theme of my address. You see the farm contributing directly to the construction of roads and getting in return roads passable only part of the year. You see there the impossibility of the farmer using modern transportation facilities. You see in this experience of mine the added cost of farm necessities and you further see the inducement toward curtailment in our purchasing. It takes no particular imagination to apply this illustration of the movement of 60 tons of limestone to a farm in Adams County, Illinois, to the hundreds of thousands of other farms, similarly situated, in every state in the Union.

Incidentally I want to say that I picked up a paper yesterday and read a statement coming from the University of Illinois, that during the last five years Illinois farmers have spread 5,000,000 tons of limestone on the farms in Illinois. That is a lot of limestone, but we are not tickling the surface so far as achieving what is necessary to be done, if it were possible to get the limestone and spread it in a practical way.

A moment ago I said that if we had had a year-round road to this farm we would have moved the limestone at our leisure and in our own trucks. In this address we are concerned with the subject of roads, but in passing I must refer to the motorization of the farm transport. The motorizing of the transport has transformed industry and commerce during the past decade. This motorization at present is denied agriculture. No one can question but that it would aid materially in solving the farm

product distribution problem. If American agriculture is to maintain its part in national progress, if it is to maintain its share in providing the American standard of living, farmers must be allowed to utilize modern machinery, equipment and tools, both in the way of production and distribution. Without motorized transportation, agriculture cannot make its proper contribution to the economic progress of the nation.

But to return to the subject—farm-to-market roads—and to consider these roads from their national standpoint, let us for the moment consider total figures. We are told that there are 2,484,822 miles of unimproved dirt roads in the United States. Add to this mileage the thousands of miles of dirt roads that have some grading and drainage and the total figures come nearer 3,000,000. It is evident that there are approximately 2,500,000 miles of road that cannot be used during part of the year and at all times these dirt roads constitute an added tax on men and equipment.

MANY FARMS STILL ON DIRT ROADS

Of the 6,250,000 farms in the United States, nearly 5,000,000 are located on dirt roads. There are 1,998,704 farms on dirt roads that boast some grading and some drainage, but there are 2,747,732 farms located on absolutely unimproved dirt roads. That makes a grand total of 4,746,436 farms out of 6,250,000. Of the balance, we find less than a million on gravel, and less than half a million on year-round surfaced roads.

And yet in spite of these startling figures, illustrating so clearly that our American road building program has so signally failed to serve American agriculture, it is significant to note that in the first session of the 70th Congress the report of the Committee on Roads of the House of Representatives contains very little testimony of interest on the subject of farm service roads. There are 652 closely printed pages of that report. The report gives the testimony of 72 different witnesses and of the 72, only four spoke at any length or with any particular emphasis on the subject of secondary roads. These four were Congressman B. Carroll Reece of Tennessee, Congressman Malcolm C. Tarver of Georgia, Carl Howard, president of the National Rural Letter Carriers' Association, and Ned H. Goodell, vice-president of the National Rural Letter Carriers' Association.

The Federal Aid Road Act of 1916 was the first statute applying the Federal aid principle to road improvement. This act provided \$75,000,000 a year for the fiscal years 1917 to 1921 and laid down the principles on which Federal aid has, with slight modification, been administered. In November of 1921, a Federal Highway Act, the Phipps-Dowell bill, was approved which established the general Federal aid highway plan designed to provide roads serving every city of 5000 population or greater and further designed to penetrate within ten miles of the homes of all the people in the country. This 1921 act was a vast improvement over the first plan suggested in that year, for earlier a bill known as the Townsend bill had been proposed. This Townsend bill provided that all Federal monies should be spent in the construction of a great system of transcontinental scenic and military roads.

Back in 1921 the American Farm Bureau Federation was the first farm organization to definitely oppose this Townsend bill and to take the first step to secure roads of some service to agriculture. The result was the adoption of the Phipps-Dowell bill outlining the policy which I have already stated. This policy, adopted in 1921, was an improvement but it has not been sufficient. In the past eight years, vast sums of money have been spent by the Federal Government. Federal appropriations have been matched by state appropriations and the final result is that only five per cent of the farms in the United States are served by year-round roads. We still have a long way to go. Often when we have discussed the lack of farm-to-market roads, it has been assumed that the figures we quoted, the illustrations we used, were drawn from the backward states—those states that have shown little or no progress in many different ways. Or it has been assumed that we have drawn our figures and illustrations from the western states with their vast distances. This is not so.

CONDITIONS IN SOME OF THE STATES

For example, turn again to my own state—Illinois—a great mid-western agricultural state, a state that has expended many millions of dollars on roads. We find in that state, under the state road system assisted by Federal aid, a total mileage of 9889 miles. This was at the close of the year 1928. Of these 9889 miles we find that 3637 are still dirt—roads impassable certain months in the year and mind you, I am speaking only of the state highway system. If we turn to the rural roads, those under country and township control, what do we find? According to the latest figures available, those at the close of 1927, there were in Illinois 87,730 miles of these rural roads and of this mileage, 74,681 were non-surfaced dirt roads.

In talking of farms and farm conditions, we always think of Iowa as this is one of the greatest farm states in the Union. Examining the same figures in Iowa that I have used for illustrating in Illinois, we find this to be the case; 7184 miles in the state system and at the end of 1928, of the 7184 miles, 2013 miles were non-surfaced dirt roads. In the rural local roads, we find that Iowa boasted a total of 96,558 miles and of this total, 89,187 miles were non-surfaced dirt roads. But the midwest alone is not the only portion of the country in which there are farmers. New York state, while it boasts the largest city in the United States and the second largest in the world, also boasts a great agricultural development. In New York state we find in the state highway system a total of 13,917 miles and of this mileage 3356 miles were still unsurfaced dirt roads. In the local rural roads we find in New York a total of 85,560 miles with more than half—to be exact—46,283 miles still unsurfaced dirt.

Pennsylvania has in its state highway system 13,330 miles and of this 4164 are still unsurfaced dirt. In its local system, Pennsylvania has 79,074 miles. Of this 63,678 miles are unsurfaced dirt. Jumping clear to the west coast, California has 6572 miles in its state highway system. Of this, 2645 miles are still unsurfaced dirt. California has a total of 78,583 miles in its local road system and of this, 58,607 miles are yet unsurfaced dirt.

In the southwest, Texas has in the state highway system 18,728 miles of which 7979 are non-surfaced dirt roads. In its local system, Texas has 169,836 miles of which 155,990 are unsurfaced dirt. These are some figures selected at random to illustrate conditions existing in various parts of the United States. The total amount of unsurfaced dirt roads in relation to the rural local roads is appalling, but this condition is truly not as startling as to see the large proportion of the state highway systems yet unsurfaced. When we think of the millions upon millions of dollars that have been spent, it seems impossible to think of how comparatively few miles have been put in permanent condition.

MORE FARM-TO-MARKET ROADS NECESSARY

On August 31, 1929, reports indicated that the total mileage of permanent roads in both Federal and state highway systems was 78,797.6 miles. At that time there were 10,321.7 miles under construction. These



SOMEWHERE IN THE UNITED STATES OF AMERICA. AN UNIMPROVED FARM-TO-MARKET ROAD

ten thousand miles were to cost \$259,691,965.90 of which \$104,613,910.33 was to be Federal money. The Panama Canal cost in the neighborhood of 370 million dollars. We have been spending on roads every two years the price of the Panama Canal and yet only five per cent of the farms in the United States are served by year-round roads.

Based on my own experience as road commissioner in Adams County, Ill., for nine years, I feel safe in saying that people receive less benefit from road money than any other money put in taxation, due to the fact that so much of the road improvement is not of a more permanent character. Money spent on temporary road improvement is in a large measure money wasted. I regret that I have to acknowledge that so much of the road improvement in Adams County during the time I was road commissioner was not of a more permanent character.

During this discussion we are trying to decide whether or not the

low cost, paved, farm-to-market roads are a national economic necessity. So far we have considered the situation as it exists today. We have come to a realization that only five per cent of the 6,250,000 farms in the United States are served by year-round roads. We have touched briefly on one or two of the effects. Now, for the moment, let us consider some of the major results of our lack of farm-to-market roads.

For the past ten years, newspapers and magazines have discussed fully the economic plight of agriculture. During the last great national political campaign, all of us heard dozens of speeches dealing with the farmer's plight. In every case the major thing discussed was the marketing of farm products. Agriculture has kept pace with industry in improving its production practices. But there has been apparently something radically wrong with the machinery used in the distribution of these products, something wrong between the time the product left the farm and when it reached the ultimate consumer. Through seven years, Congress carefully considered this problem. This year we have seen a special session of Congress called with the express purpose of dealing with the agricultural problem. Out of this special session has come legislation which has resulted in the setting up of a Federal Farm Board. This Federal Farm Board is charged with the duty of effecting improvements in the marketing of farm produce.

It does not take any great study of the agricultural situation to see that the difficulties in the distribution of farm produce starts right at the farmer's gate. The economic life of the United States is geared to rapid transportation. The airplane, the bus, the truck, the automobile, the electric line and fast freights move the commerce of the nation, but the produce of the farm moves from the farm to the next transportation system on the same sort of road that existed a hundred years ago and either by the same general device used a hundred years ago or if by modern motorized equipment, with the burden of a terrific equipment wear-and-tear tax.

WILL STIMULATE MOTOR CAR PRODUCTION

One of the problems of the marketing of farm produce is occasioned by the market glut following the harvest of particular crops. One reason for that glut is the fact that the farmer must move his produce to market during the period of a few weeks when his dirt road is dry and hard. Year-round roads would enable him to spread this period over a number of months and that would prevent this seasonal glut that penalizes American agriculture millions of dollars each year.

A natural sequence to the effect of a dirt road on agricultural use of motor transportation is its effect on the motor industry. I believe you have another talk on this program this morning having to do with the effect of farm-to-market roads on the automobile industry. I was struck with figures recently presented showing that at the end of 1927 there were only 44 yards of high type highway for every motor vehicle registered. And someone has recently stated that if the new cars manufactured each year were placed end to end, they would just about stretch the length of the paved roads put in during the year. In March, 1929,

in the *Atlantic Monthly*, a writer—Earnest Elmo Calkins—had this to say:

"Before the buyer of motor cars realizes that there is no place to drive and stops buying, the movement should be under way to multiply the available road area five-fold by surfacing all existing roads and the motor industry, four million strong, is the unit to undertake it. It has the vested interest in good roads, and is in itself a large enough body to influence the public."

I note that statistics for the last several months show a steady decline in the number of motor cars manufactured. Therefore, the effect of the lack of an adequate secondary road system does not end with the consideration of the marketing of farm products nor its relationship to the automobile industry. There are many other matters of grave importance. Let me refer to the annual farm fire loss. Each year in rural fires 3500 people are burned to death. Each year farm fires destroy \$150,000,000 worth of farm buildings, equipment, stored crops and stock.

PAVED ROADS AND RURAL FIRE PROTECTION

A little while ago Major General George O. Squier, U. S. A. retired, developed a plan advocating motorized fire-fighting apparatus with a rural fire-fighting company in each township, equipped with chemical truck with a driver that could be rushed to the aid of any farmer whose house, barn or haystack happened to catch fire. The need of such a fire-protection system for American agriculture is apparent from the figures I have just quoted. I believe that such a plan is totally impossible



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today with only five per cent of our farms being served by year-round roads. Under present conditions, during the months when fires are most frequent, such fire-fighting equipment could not get within a mile of five million of the farm homes in the United States.

While this inability to develop adequate fire protection to rural America is responsible for a tremendous economic loss, I think it is greatly overshadowed by the effect of the mud barrier on rural education. The little one-room school with its meager equipment and poorly paid teacher is rapidly giving way to the consolidated or centralized, well-equipped, sufficiently-manned public school. This is essential if the farm youth of America is to be fitted for modern life.

BENEFITS DERIVED FROM PAVED ROADS

But the consolidated or centralized school presents a problem. It lengthens the distance from the farm home to the school house. It makes necessary bus or truck transportation for the children. Such transportation cannot be economically available for farm children located off the more permanent surfaced highways. A five-year survey by the Bureau of Public Roads indicates emphatically the effect of bad roads on school attendance in a striking way.

Comparable to the restriction on the educational development of rural America is the increased cost of sickness due to unsurfaced dirt roads. In the current issue of the *Bureau Farmer*, official publication of the American Farm Bureau, appears an editorial setting forth some startling figures regarding the cost of medical care for the average farm family. In this editorial it is shown that a recent survey gives the average cost per family for medical-dental-hospital care at \$104.94 a year. It is shown that the average farm family pays \$7.63 to a doctor to make one home call and 13 per cent pay more than \$15.00. It is pointed out that the road condition is the main factor in this high cost of medical attention. The fact that the automobile has become the chief method of travel is an actual hindrance to farmers who can be reached only through unimproved dirt roads. The facts of this survey of medical cost show that in one state like Iowa, the farm people spend around 21 million dollars a year for medical attention and that a large proportion of this cost is chargeable directly to high cost transportation due to unimproved dirt roads.

A while ago I spoke of the effect of this road situation on the automobile industry. This effect is just as noticeable in the business of the merchants and tradesmen who serve the farmers of the country. With more than two-thirds of the farmers barred from the market-place from two to six months a year by bad roads, it is very reasonable to assume that farm people do not purchase the amount of merchandise they would if they could reach the market every day. This directly affects the groceryman, the motion picture industry, the clothing store and all other lines of commerce and business.

Closely related to this thought is the possibility of the small town business man broadening his market through an adequate rural delivery system. A well developed system of local roads would enable such a development to take place. It is much more economical for one mer-

chant to deliver merchandise to 50 farmers than for the 50 farmers to take so much of their time individually to go into town to the store to get their merchandise. A secondary road system that would permit a proper delivery system would provide a real economy in national distribution. It would enlarge markets and increase consumption of manufactured products.

FEDERAL AID FOR SECONDARY ROADS

In considering the necessity for an adequate secondary road system, pleasure must not be overlooked. A secondary road system would offer a far superior and far more appealing pleasure road than main trunk highways with their heavy bus and truck traffic. It would offer a new incentive for motor excursions for town and city people. It would effectively break down the barrier between the real rural America and the metropolitan areas. It would provide an absolutely new appeal to the city motorist seeking pleasure.

In leaving a discussion of some of the main factors indicating the economic necessity of the development of farm service roads, one must mention briefly the appalling loss of life and destruction of property in auto accidents due in a large measure to congestion on trunk lines. The development of an adequate secondary road system would relieve this congestion and is important from a safety standpoint.

Those are some of the important factors that the American farmer considers in his contemplation of the present road problem. The Farm Bureau organization, consisting as it does of 15,000 community units, 1837 organized counties, of 45 state federations, has been tackling various phases of this problem in a small way during the past ten years. We now propose to go forth in an energetic national campaign, national in the sense that it will be stimulated, supported and sponsored by the national Farm Bureau, but local in the sense that it will be handled directly in 1837 counties, to bring about a proper understanding of this



ASPHALT SURFACE-TREATED FARM-TO-MARKET LOW COST ROAD IN NORTH CAROLINA

road situation and to secure the adoption of a road building plan that will take care of the farmer's road needs.

For every mile of trunk line built we shall insist that there be so many miles of secondary or farm-to-market roads. We believe it is false economy to build trunk lines without secondary feeder lines to give the main lines their full value. We do not feel that our efforts to secure adequate secondary road systems will necessarily increase taxation. The amount of money now going into roads may be sufficient. We shall seek a more equitable proportion of that money. We shall seek Federal aid for secondary roads. We feel justified in asking that a portion of the Federal money be diverted to secondary roads because of the general increase in prosperity that would follow such a development. Such a development also would add to the value of already established trunk lines.

BETTER ROADS FOR RURAL MAIL DELIVERY

We feel that we are justified in seeking Federal aid for secondary roads because of the use made of these roads by the government for the Post Office Department. There are in the United States 45,000 rural mail carriers using 1,270,746 miles of rural road. Congressman Reece of Tennessee estimates that if the roads used by these rural mail carriers were year-round roads, the consolidation of routes and other similar economies would make a saving of at least 25 million dollars annually to the Post Office Department. In testimony that has been submitted to Congressional committees, representatives of state associations of rural letter carriers have pointed out the terrific toll placed on equipment and men through bad roads that must now be used by rural mail carriers.

In all states we shall continue our fight to see that an adequate proportion of the funds for road building purposes are directed to the development of secondary roads. An example of what can be done by our state organizations is the outstanding piece of work done by our New York state federation. Through the effort of the federation was secured a reapportionment of road funds which made available 11 million dollars a year for secondary highways in New York. Twenty per cent of the gas tax goes back to the counties for lateral roads. The state assumes full maintenance costs and the like.

Commenting on the result of this campaign, the New York edition of the *Bureau Farmer* in May of this year said:

The importance of this particular measure to rural people cannot be overestimated. Less than one-third of the farms in this state are now located on improved roads. With the money made available by this new law, the other two-thirds of the farm population will be brought nearer to their markets, making it possible to step up their whole farm operation.

It is our purpose to bring about a similar result in all our great agricultural states.

PRESIDENT LAW: Tying in quite well with the very able paper by Mr. Thompson, we had hoped to have an address this morning on the "Elimination of Traffic Congestion on Main Highways by the Improve-

ment of Farm-to-Market Roads," to be presented by Mr. Ernest N. Smith, executive vice-president of the American Automobile Association. Unfortunately Mr. Smith is unable to be with us. He has, however, sent a letter which I will ask the secretary, Mr. Pennybacker, to read.

Letter from Ernest N. Smith, Washington, D. C.
Executive Vice-President, American Automobile Association

Washington, D. C.,
 September 28, 1929.

Mr. J. E. Pennybacker, General Manager,
 The Asphalt Association,
 441 Lexington Avenue,
 New York, N. Y.

My dear Mr. Pennybacker:

As previously explained to you, it is with the greatest regret that because of previous engagements I am unable to accept your kind invitation to be present and address your meeting at West Baden.

This association is actively interested in the use and improvement of secondary roads in this country. In the first place our improved road system is wholly inadequate today to the demands being made upon it, and the growth of improved roads has not kept pace with the growth of rubber-tired transportation.

Because of increasing road congestion, because of the fact that unimpeded speed is the tempo of the times, and because there is an increasing demand for new roads upon the part of travelers who have often covered the old roads, there is an insistent demand that more improved roads be constructed.

We are promoting a campaign to that end in all constructive ways.

Nearly half of all the roads in the world are located in the United States, and only one-sixth of those may be said to be improved all-weather roads. And 85 per cent of all the motor cars of the world are located in the United States.

Fundamentally, our problem is to increase the mileage of improved roads as rapidly as possible.

I am sorry I cannot be present at your meeting this year to tell you more of our enthusiasm with reference to this program and to discuss with you ways and means to effectuate it.

Very truly yours,

ERNEST N. SMITH,
 Executive Vice-President.

SECRETARY PENNYBACKER: While I am on my feet, it might be just as well to read the following telegram from Mr. C. N. Conner, of the American Road Builders' Association, Washington, D. C.:

J. E. Pennybacker,
 General Manager, The Asphalt Association,
 West Baden, Indiana.

From personal observations and testimonials of others, low cost roads are at last receiving deserved attention. Your present conference will be of far-reaching importance in the most fertile field of highway work. I wish you every success and large attendance at your convention, and regret my absence.

C. N. CONNER.

PRESIDENT LAW: Of all the factors that play a part in this great program of road improvement, I am sure there is none more important than the part played by the successful asphalt paving contractor. With adequate funds and the best kind of engineering, I am sure we could not build our roads without the aid of the skilled artisans who finally put them into place. The contractor is really the means of converting the funds of our taxpayers and the knowledge and skill of our engineers into the actual service which we all appreciate so much, and an organization which has for its purpose the improvement of this important link of the chain is the American Asphalt Paving Association of Chicago. Its president, Mr. Frank O. Hodson, is with us and will be glad to talk to you. I am pleased to present to you Mr. Hodson.

Address of Mr. Frank O. Hodson, Gary, Ind.

President of the American Asphalt Paving Association

Mr. Chairman, Gentlemen: First, please let me assure you most sincerely that the American Asphalt Paving Association is deeply appreciative of the very kind invitation of the Program Committee for me thus to appear before this splendid gathering.

The American Asphalt Paving Association, as you know, is new. There always seems to be something new coming on in the world and I guess we are no exception. Economic necessity drove us to it. These economic considerations are so well comprehended by all that there is no need of exposition here. But while economic pressure played its part, still the primary and compelling influence was the realization that only through organized cooperative effort, or work with our common business associates, could we get anywhere in the solution of our economic problem, which, I am sure all will agree, is a problem common to and with us all—maintaining our position while carrying on plans for its improvement and ultimate stability and profit. And when we reflect on the various and sundry circumstances and conditions in which we are enmeshed, both internal and external, it requires no stretch of the imagination to perceive that we have a pretty stiff job ahead of us, a job,—I say this with greatest gravity,—requiring profound business statesmanship in carrying it forward to success.

MEMBERSHIP IS INCREASING

Our association is composed of contractors owning or operating hot-mix asphalt paving plants, actively engaged in the business of contracting for the construction, reconstruction, or maintenance of asphalt roads, streets or pavements in the high-type pavement field.

We formally organized on April 27 of this year with 21 charter members, representative of nine states. Membership drive activities did not get under way until the middle of May. Then we were held up through September and October by reason of the season's paving activities. It was then inopportune to visit contractors who were so busy on

what little work they had. But despite these delays the membership has finally at this date mounted to 92, representative of fifteen states, with operations of the members extending into as many more states. Our membership principally is representative of the central states where it is practically 100 per cent complete among the contractors in that territory.

Our object or purpose is outlined briefly in two paragraphs from our constitution and by-laws. First, to foster the general interests of our members and those in any way related by common business ties. Second, to maintain harmonious relations and work constructively with all organized representative agencies, associations, societies or groups, civil or governmental, actively interested in the engineering or promotion of asphalt paving.

PLANS FOR COOPERATION WITH OTHERS

Our fundamental thought is to so organize and conduct ourselves as to be able effectively to cooperate and work with others for the common good of all, and this includes the public. We felt that in organizing the American Asphalt Paving Association we completed the economic trade organization chain in the asphalt paving industry. The producers of asphalt function through The Asphalt Association, the designers of asphalt pavement operate by virtue of the Association of Asphalt Paving Technologists, and the contractors now operate through the American Asphalt Paving Association,—a three-legged stool as it were. We regard ourselves simply as a complement in making up the whole.

So it is in a spirit of genuine desire to be helpful constructively in every way possible that I present the American Asphalt Paving Association. We are not seeking the limelight. We only want to be useful, lending what constructive business sense we may possess to that of the others, in a common effort for the common good.

PRESIDENT LAW: We have heard a good deal about the low cost road. One important phase of the subject is the matter of how we are going to obtain these improvements. An important factor entering into that subject is the question of research. We have with us this morning a gentleman who perhaps does not need to be introduced. I am sure he is well known to all of us by his position on the Advisory Board of Highway Research. I take pleasure in introducing Mr. R. W. Crum, who will talk to us on the subject of "Research as a Factor in Solving the Low Cost Road Problem." Mr. Crum!

Research a Factor in Solving the Low Cost Road Problem

By R. W. Crum, Washington, D. C.

Director, Advisory Board on Highway Research, National Research Council

It no doubt appears strange to persons not themselves engaged in highway work that there should be so much talk of highway research. With the enormous expenditures being made for highways it is perhaps

natural for them to ask, "Why have not these highway problems been solved long before this?" The answer is that since the advent of the motor vehicle, the problems will not stand still long enough for us to overtake them and put them behind us. However, I think we are beginning to catch up. At least I think we now realize more nearly what the pressing problems are.

I remember an Iowa farmer who became much exasperated over the waste of the taxpayer's money as evidenced by a party of surveyors who operated along his road for some time. He went to the county engineer and demanded to know the reason for the foolishness. "Why," said the engineer, "they have to get the data so that the road can be properly designed." This was too absurd for the old man. "What," he said, "is there to design about a road?" I suppose he would be even more astonished at a need for extensive research on low cost roads, but I am sure all highway engineers will agree that the solution of the farm-to-market road problem is the most difficult and pressing problem of all.

PROBLEMS INVOLVED IN LOW COST ROADS

We know how to raise the money for a state highway system and how to build durable and adequate roads thereon, but how to get money enough to build the vast mileage of serviceable, all-year, farm-to-farm roads needed on the secondary systems, and how to build such roads adequately on the limited funds that can be secured, are problems that challenge the best thought and professional skill of highway officials and engineers. The help of penetrating and thorough research work will be needed in the solution of these problems.

Each road should be improved to the extent that adequate service will be given to the users of that road at the lowest possible cost for the highway transportation. In the item of transportation cost must be included both the cost of vehicle operation and the cost of the roadway. A detailed analysis of this statement as applied to low cost roads would reveal innumerable questions for which we do not at the present time have exact answers. Hence the need for research work.

Some of the major questions raised at once in considering such a program for road improvement are these:

- (1) How is the money to be raised to pay for these roads?
- (2) What will the roads and their use cost?
- (3) What design of roadway and surfacing will serve the traffic adequately at the lowest cost?

It is not the purpose of this paper to present answers to any of these questions, but merely to state some of the problems involved and call attention to the research needed for their solution.

HOW IS MONEY TO BE RAISED TO PAY FOR THESE ROADS?

HIGHWAY FINANCE

The general problem is the equitable distribution of the cost of providing highway service in proportion to the benefits derived therefrom. It may be assumed in the case of secondary roads that benefits accrue in

three ways: (I) general benefit to community life; (II) special benefit to abutting property, and (III) benefits to the individual user of the roads. Revenues should be raised from each of these three sources, the unanswered questions being: "What portion should each source contribute, and in what ratio should the funds be allocated among the through traffic highways, the community roads, the purely local roads, and municipal streets?"

I—GENERAL TAXATION

To what extent should the general public contribute through property taxes, and what proportion should be expended upon each of the three classes of roads: (a) through traffic highways, (b) community roads, and (c) purely local roads. In other words, to what extent should property taxes be levied in the interest of each of the three classes of roads? On the one extreme we have the local road, of importance only to the residents along the road and used only by them or by those who seek access to them. On the other extreme we have the through highway used by everyone in the community as well as by others from outside who are passing through. To what extent does the improvement of each of the three classes of roads benefit the entire community, irrespective of the actual use of the roads?

Research Needed

(1) Studies of economic changes in typical communities to show the benefit of road development in the life of the community.

(2) Studies in typical communities to show the stage of road improvement at which the benefits to the road user begin to overshadow the general benefits. For instance, a low type of surfacing might be sufficient for general community needs, although a high type may be needed to care for the traffic adequately.

II—ASSESSMENT AGAINST ABUTTING PROPERTY

Agricultural property is undoubtedly benefited by proximity to a good road over which its produce can be marketed and also to some degree by the effect of the road improvement on its desirability as a home site. The question is, at what stage in road improvement does the special benefit cease to increase? These benefits can be measured by the increase in selling price of the land caused by the road improvement, and in the absence of such cost data by farm records as to cost of marketing and savings due to timeliness in marketing.

Research Needed

(1) Studies in a number of scattered communities of the effects of different types of road improvement upon land values and marketing conditions, and the effect which distance from marketing centers has upon land values, and upon the type of road necessary for that service.

III—MOTOR VEHICLE TAXES

Taxes imposed upon vehicles are of three kinds at the present time: (1) general property taxes; (2) license and registration fees, and (3)

taxes on gasoline. It may be assumed that the most equitable taxes on the vehicle are those based upon the amount of use of the road and upon the destructive effect of the vehicle upon the road. The tax on gasoline is the best measure yet proposed for a tax based upon use of the road. The destructive effects of different types of vehicles have not yet been evaluated. Information is needed as to the costs of vehicle operation and as to the costs of providing highway service adequate for different classes of traffic. For instance, a six-inch structure might be heavy enough for a large part of the traffic on a certain highway, but the presence of bus and truck traffic might make necessary an eight-inch structure. In such a case a tax rate based on mileage alone might not distribute the burden equitably. On the other hand, it might not be equitable to saddle all the cost of the extra two inches of thickness upon the buses and trucks because the public benefits from the ability of the buses and trucks to operate over the road.

Another problem of immediate importance is the distribution of the proceeds of gas or other vehicle taxes, as between the various classes of rural roads and city streets. If such taxes are a measure of road use by the vehicles, all of the roads used have some claim upon the proceeds of the tax, but as yet no data are available showing what the relative amounts should be. The proportion of a gasoline tax, for instance, that should go to the various classes of roads, and to the city streets will depend upon the relative amount of traffic and upon the proportion of the cost of each class that should be borne by the road user.

Research Needed

(1) Vehicle operating costs, for various types of vehicles, on various kinds of road surfaces.

(2) Costs of providing highway service for various kinds of traffic. (Note: These will be further discussed under "Highway Transportation Costs.")

(3) Relative use of different classes of roads. Traffic surveys on all classes.

IV—USE OF CREDIT

If roads are constructed by means of bond issues, they can be put into service sooner, but the earlier expenditure of capital will mean additional interest charges which will increase the net annual cost of providing the highway service. The question is whether or not the savings in total highway transportation costs during the extra years of service will compensate for the additional roadway cost. The answer to this in any given case will depend upon the available knowledge of costs of transportation over various types of road surfaces and upon the amount of traffic.

Research Needed

(1) Data on highway transportation costs. (Note: To be further discussed under "Highway Transportation Costs.")

(2) Several states having already financed road improvement programs through bond issues, studies of economic conditions in those states

as related to highway transportation should go far to answer the question as to the practical value of thus speeding up the road building program.

WHAT WILL THE ROADS AND THEIR USE COST?

HIGHWAY TRANSPORTATION COSTS

The annual cost of transportation over any length of highway consists of the yearly cost of providing the roadway ready for service plus the cost of operation of all vehicles while using that particular road during the year.

A knowledge of all of the factors entering into this total cost is needed to furnish a basis, for equitable taxation of vehicles, for the proper layout of highway improvement programs, and for the economic design of the roads. In other words, the highway transportation cost is a dominant factor in the solution of all of the major highway problems.

In the case of heavy traffic roads the vehicle operating cost is the predominating factor. On very light traffic roads the roadway cost predominates. If the vehicle owners are to be expected to pay a large part of the highway service bill, they should be taxed in proportion to the extent to which each uses the roads, and in proportion to the effect of his vehicle upon the annual cost of providing the highway. Methods for accurate determination of these factors depend upon the further study of costs.

Vehicle operating costs are affected by grades, curvature, location and by the type of road surface. In planning an improvement program the type of improvement should be used for which the annual transportation cost will be the lowest at which the expected traffic can be adequately served. In designing the road itself, consideration should be given to the effect of such features as grades, alignment and cross section upon the total transportation cost. Knowledge of the effects of such features upon such items as gasoline and oil consumption, tractive resistance, and upon schedule speeds is needed for economic designing.

The principal elements upon which data are lacking in connection with roadway costs are the effects of quantity and kind of traffic upon maintenance costs, and the rate of depreciation and salvage value of various types of roads under various conditions. More data are needed on all of the items of vehicle costs that are affected by mileage, for these are the items that are also affected by the roadway characteristics.

Research Needed

(1.) Collection of data on relation of maintenance costs to traffic for all types of surfaces. Promotion of the use of uniform records of cost and traffic.

(2.) Collection of data on cost of resurfacing and on salvage value.

(3.) Study of rates of depreciation.

(4.) Collection of data on vehicle operating costs, especially on buses and trucks.

(5.) Study of factors, outside of vehicle design, that affect operating costs.

(a) Road surface (tractive resistance).

- (b) Grade and alignment.
- (c) Tire wear.
- (d) Car maintenance (mechanical depreciation).
- (e) Cost of impediments to free flow of traffic.

HOW SHALL THE ROAD BE DESIGNED TO GIVE ADEQUATE SERVICE AT THE LEAST COST?

ROADWAY

Location, grades, alignment and width have a large effect upon transportation costs, traffic capacity and safety. Their effects upon vehicle costs are measured by tractive resistance, both rolling and wind resistance, fuel consumption, mileage, schedule speeds and traffic capacity. Their effects upon safety must be evaluated from accident statistics. Their effect on roadway costs, outside of construction is measured by the cost of maintenance. The principal determining factors in establishing these features of a highway are quantity and kind of traffic and consideration of public safety. Too often the proper design indicated by study of these various factors will have to be modified on account of scarcity of funds. However, a knowledge of what is right will point the way to the use of what money there is to the best advantage. The research needed to help evaluate these factors is largely a matter of effects upon transportation costs, and the principal items were listed under that heading.

SURFACING

(Includes—Subgrade and Wearing Course)

As in most other phases of highway work, the general problem is to provide the surface that will take care of the traffic satisfactorily at the least cost for highway transportation. The choice of type and design of surface are affected by the character of the subgrade, the amount and kind of traffic, climate and topography, the annual cost of various types of surface and safety precautions.

Subgrade

The factors, according to Hogentogler and Terzaghi, involved in the study of the relationship between subgrade soil and road surfaces are as follows: "Subgrade properties, due primarily to the raw constituents of the soil, also those due to the field conditions under which the soil exists; pavement conditions caused entirely by the subgrade support, and conditions only partially caused by the characteristics of the subgrade; individual conditions of subgrade support which produce particular conditions in the pavement; the relative influence which similar subgrade conditions exert upon pavements different in type; the soil characteristics disclosed by a particular group of laboratory test results; the individual raw constituents which cause the soil to exhibit particular physical properties; the relative influence which the arbitrary test procedure and the physical characteristics of the raw constituents of soils exert upon the results furnished by laboratory tests, and the extent to which the physical manifestations disclosed by the laboratory tests serve to explain the behavior of soils when subjected to field conditions."

Pavement behavior may depend upon the character of the subgrade soil material (raw constituents), upon the structure of the soil in its natural state (dense or loose, homogeneous or full of cracks and root holes), upon the soil profile (variation in depth of the different soil zones and the relative occurrence of permeable and impermeable strata), upon adjacent topography (through its influence upon the occurrence of surface and underground water), upon climatic conditions (well distributed or intermittent occurrence of rainfall and presence or absence of frost action), or upon any combination of these variables.

Needed Research (Subgrade)

(1) Continued development of laboratory tests to aid in classification and identification of soils.

(2) Relationships between laboratory tests and properties and behavior of soils in roads.

(3) Study of the behavior of soils under various moisture conditions.

(4) Effects of surface treatments of subgrades.

(5) Effects of subgrade treatments on supporting quality.

(6) Surveys of relationships between soil characteristics and road surfacing behavior.

TRAFFIC, EFFECTS ON DESIGN OF SURFACE

The effects of the quantity, kind and weight of traffic are the dominating factors in the design of the road surface since the only reason for building the road is to serve the vehicles that use it. The type of surface should be the one which will accommodate the expected traffic at the least transportation cost. For instance, a low cost road with high maintenance costs may be more economical for a light traffic road than a more expensive but more durable type, because in such a case the total saving in operating costs to the small number of vehicles using the road, by having a higher type road might not be large enough to overcome the high annual charge for interest due to the greater first cost of the high type road.

The physical effects of the traffic upon the surface are caused by speed, weight and impact, and are ultimately measured in terms of cost of upkeep. A difficult problem in each specific case is the determination of the controlling weight of traffic unit upon which to base the design. Information as to the frequency of use by the heavier vehicles is important.

Needed Research

(1) Wheel load intensities.

(2) Distribution of wheel loads through various surfaces.

(3) Effect of volume and weight of traffic on maintenance costs of various surface types.

(4) Effect of speed on road surfaces.

Climate and Topography

Some road surface deterioration is caused by action of the elements. Rainfall and extremes of temperature in some parts of the country are

determining factors in design. The principal effect of ordinary topographical conditions upon structural design is the provision that must be made for surface water run off. Unusual conditions caused by such factors as landslides, subsistence, etc., are troublesome in some regions.

Needed Research

- (1) Data on run-off on various grades under various intensities of rainfall.
- (2) Data on landslides.
- (3) Data on subsistence.
- (4) Methods for building fills on marshy ground.

Road Surface Types

Road surfaces may be classified as high, intermediate and low type according to their suitability for heavy traffic main thoroughfares, medium traffic thoroughfares and community roads, and light traffic local roads. The principal problems in connection with all of them have to do with the development of the necessary characteristics to handle the traffic satisfactorily at the minimum transportation cost.

The intermediate types of surfaces include waterbound macadam, traffic bound surfaces of various materials, bituminous macadam and bituminous bound surfaces. The problem is largely one of economy, as the principal objective is to build roads that can be maintained in a satisfactory condition at reasonable cost for highway transportation. The relation between amount and kind of traffic and maintenance cost is especially important on these roads. From a structural standpoint the problems have to do with the effects of climate and traffic upon durability. Much of the needed research has to do with the materials. Development of road surfaces of this class will be largely a matter of experimentation in service. More detailed reports of these experiments should be made.

Needed Research

- (1) Data on effects of weather and climate on various combinations of materials.
- (2) Data on effects of traffic.
- (3) Rate of wear of waterbound and traffic bound roads and effect of dust prevention measures thereon.
- (4) Salvage value of such surfaces in connection with change to higher types.
- (5) Critical study of various types of surfaces now in use.
- (6) Design of cross section for bituminous macadam.
- (7) Characteristics and methods of testing materials.
- (8) Data on relation between quantity and kind of traffic and maintenance costs.

The low type surfaces include dirt, topsoil, sand-clay, etc. The problem is to provide a road at very slight cost that will furnish approximately all weather service for light traffic. Topsoil and sand-clay, where available, have been found reasonably satisfactory. The problem is much more pressing in the great agricultural regions where the cost of hauling surfacing material is prohibitive for these roads.

Needed Research

(1) Investigation of possible methods of stabilizing soil to form a road surface.

It is evident from this brief analysis that solution of the low cost road problem is dependent upon sound information on the cost of highway transportation, under a wide range of conditions, and that as yet many of the elements that go to make up the cost are very imperfectly understood. The only way to acquire this knowledge and to make it useful is by means of *research*, and that is why research is a large factor in solving the low cost road problem.

DISCUSSION

PRESIDENT LAW: I am sure we all appreciate the very timely paper by Mr. Crum on this important subject of research in connection with the secondary roads. This is really our first technical paper on the program of the conference, and it is quite appropriate, I think, that it should be discussed. We have plenty of time at our disposal and if you gentlemen want to say anything or ask any questions, I am sure we will be glad to hear from you. Is there any discussion of Mr. Crum's paper?

MR. S. R. MURRAY, MILWAUKEE, WIS.: I would like to say that I agree heartily with nearly everything that the speaker has said, and especially would like to see the results of the experiments made more generally known. Personally I have been interested in the asphalt paving business for thirty-seven years, and of course during that time I have made a great many experiments. There are, I believe, a great many others in the same boat that I am in, and if they would make known the results of the experiments which they themselves have made, I believe it would tend largely to solve this problem of inexpensive types of asphaltic road, for the secondary systems as well as for the main highways.

PRESIDENT LAW: That is a very good suggestion indeed. We will be glad to hear from others.

MR. PREVOST HUBBARD, NEW YORK, N. Y.: It occurs to me that some of the gentlemen here may not be familiar with what the Advisory Board on Highway Research has already done in assembling information on low cost roads. If Mr. Crum would tell us, in a few words, the results of Mr. Conner's investigation in endeavoring to present a picture of the status of low cost road work at the present time, it might be of interest.

MR. R. W. CRUM: I suppose you have heard of the investigations of highway construction conducted over a space of three years, gathering information on the present status of the intermediate and low type road. The work was done by Mr. Conner, now of the American Road Builders' Association. The data gathered by him were published in a three hundred page volume which comprises an extremely interesting report and contains a large amount of valuable information. Probably it is the only place in which you can find so much pertaining to this particular subject. This publication is available at practically all the road-building organizations.

PRESIDENT LAW: Anybody else?

PROFESSOR F. H. ENO, COLUMBUS, OHIO: Mr. Crum has laid out for us in his paper some of the means of research to provide cheaper and better roads for the secondary system. It remains for us to collect and try out by experimental methods many ways of developing those second-class roads. It seems to me that the great problem before the highway constructor today is the provision of the secondary road for the farmer, whose case was so ably presented here as to the need of such roads by Mr. Thompson. One of the things that can be done in an experimental way, it seems to me, is to test out the treatment of soils for plain earth roads. We cannot do, in the northern part of the country, what they are doing in Georgia, North Carolina and other sections of the southern part of the country with surface soil roads so well, because our winter conditions are so different. When our spring comes after the winter season we have roads that have gone thoroughly to pieces because of the disintegrating effect of the frost and thaws. This they do not have in the South. We have to treat our roads with something that will withstand frost or prevent a certain amount of freezing.

Whether asphaltic combinations can be made with the soils cheaply that will prevent that, is up to experimentation, which may be partly conducted in the laboratory; but an effective and efficient way to do it is by actual, practical experimentation in the field. To illustrate what I mean by that let me say that I am doing some such work in Ohio as experimental work for the U. S. Bureau of Public Roads and the State Highway Department of Ohio. So far we have not come to the point where we care to publish any of our results particularly, but to illustrate something let me say that I went to a road about two months ago and applied some of these materials on the surface before some traffic-bound treatment was made. The night before it had rained all night, and next morning the road was a sea of mud. The question was how could we make any application? The applications I intended to make that day were with oil, tar and materials of that type. I thought by scarifying the road and lifting the mud a little we might be able to make an oil application. We did that, just after breaking the soil below the mud and applying kerosene oil. The moment the kerosene oil had been applied I was able to walk across the road without getting any mud on my shoes at all. Before that I had sunk in the mud.

The application of the kerosene had deadened the effect of the water. How much that will affect an application to gravel, cinders and slag I do not know. I will be able to say later on, but we want more of that kind of work to be done. One of the things that I think Mr. Crum's paper has brought out is the importance of collecting what has been done. This speaker over here just mentioned many cases throughout our state where certain treatment has been given roads, either by the local residents or by the highway department, just as a remedy for a temporary condition. If that can be reported, together with the information as to how long it lasted, and how it worked in with the subsequent construction of the road, I think it would be very valuable.

For instance, the engineer in Ohio reported to me some time ago that in this traffic-bound road work he found, in little unincorporated villages where they had tried to lay the dust, that sometimes they used oil and

sometimes they used some other application, and whenever he got into these places with traffic-bound roads they packed down and became usable in half the time that the roads did out in the country where no treatment had been given. If the ordinary country roads had been treated before they were surfaced with traffic-bound materials, they would have become smooth much quicker. I noted a month ago when I went over a traffic-bound road in southern Ohio that in general it was dusty and had more or less loose surface material and was objectionable to the traveler, but when I examined in front of each of the farm homes along there the road was nice and smooth and had packed down in good shape. I could not tell whether this was due to the use of calcium chloride or not.

When I arrived at the headquarters offices of the county, the engineer said they had used no oil but they had used calcium chloride, and wherever it was used the road was doubly as good as it was where calcium chloride had not been used. If we could get information of that sort collected together and circulated, it would help the second-class road improvement question.

PRESIDENT LAW: Hearing no other discussion and having reached the last paper on the morning's session, there is little ahead except to adjourn for the afternoon session at 2 o'clock. Before formally adjourning, are there any items of business?

MR. C. S. LEE of New York: I have a motion I would like to make at this time, if it is in order. The motion is that the following gentlemen be appointed by the chair to constitute the Resolutions Committee for this conference, this committee to be called to meet at 8 o'clock tonight in the executive offices of the hotel, to the left of the lobby on the first floor: Mr. A. K. Vickery, Denver, Colo.; Mr. H. S. Fairbank, Washington, D. C.; Mr. F. B. Curran, Washington, D. C.; Mr. A. H. Hinkle, Indianapolis, Ind.; Mr. F. A. Hogan, Toronto, Can.; Mr. C. C. Lakin, Chicago, Ill.; Mr. C. S. Lee, New York City; Mr. R. H. Simpson, Columbus, Ohio; Mr. H. J. Hughes, Cambridge, Mass.; Mr. B. E. Gray, Keyser, W. Va.; Mr. J. T. Bullen, Shreveport, La.; Mr. Charles S. Pope, Sacramento, Cal.; Mr. Bryson Vallas, New Orleans, La.; Mr. E. R. Dutton, Minneapolis, Minn., and Mr. B. P. McWhorter, Atlanta, Ga.

PRESIDENT LAW: Gentlemen, you have heard the motion. Is there a second?

The motion was seconded and unanimously carried.

PRESIDENT LAW: There being nothing further before the conference I will now declare the meeting adjourned until 2 o'clock.

SECOND SESSION

OCTOBER 29, 1929, 2 P. M.

A. J. WEDEKING, CHAIRMAN, INDIANA HIGHWAY COMMISSION,
PRESIDING

CHAIRMAN A. J. WEDEKING: To those of you who are from other states it will be interesting to you to know that in Indiana we control things pretty well. The director of our State Highway Commission repeated to you this morning a beautiful poem in which it was asserted that the sun shines brighter in Indiana. Some of you who came down here yesterday looked rather incredulously at one another when he read that beautiful little verse commenting on how much more brightly the sun shines in Indiana than anywhere else. For fear that you might have regarded him as being inconsistent with the facts in the case we have arranged to have the sun shine more brightly this afternoon than any other time. So Mr. Brown's position in this matter was well taken. We control everything that way, here in Indiana. We leave nothing to chance and there is only one organization before which we of the Highway Department bow our heads in humility, and that is the United States Bureau of Public Roads. This afternoon I am pleased to present to you, as the first feature of this program, a man from the Bureau of Public Roads. I am not going to make a long introductory speech. I heard a man say just the other day that introductory speeches were a good deal like after-dinner speeches; it would be a fine thing if all after-dinner speakers were laid end to end. (Laughter.) I am pleased to introduce to you at this time a man who is chairman of the Research Committee of the Bureau of Public Roads, Mr. H. S. Fairbank, who will now address you.

Cooperative Research and Standardization of Low Cost Road Improvement

Federal Government Participation

By H. S. Fairbank, Washington, D. C.

Chairman, Research Committee, United States Bureau of Public Roads

When Mr. E. W. James, speaking before the Seventh Annual Asphalt Paving Conference at New Orleans, called attention to the need of experiments to determine how best to use light oil products in low cost road building, he expressed the hope of the Bureau of Public Roads that the industry would find in the development of that broad field for the utilization of its products an opportunity worthy of its best efforts and equal at least to that offered in the necessarily limited field of high-class pavement

construction. Examination of the program of this, the Eighth Asphalt Paving Conference, suggests that the industry approved the suggestion.

The Bureau's interest in the development of methods of low cost road construction is founded upon knowledge of the need of such methods for the improvement of literally hundreds of thousands of miles of roads on which the present traffic is of such proportions as to require a smooth, dustless, year-round surface, but not so great as to justify the necessary expenditure for a surface of high type. We have been confronted directly with this need in connection with the improvement of roads in the national forests and parks, which are our special responsibility. We know that there are many miles of main roads in certain regions, particularly in the West and South, which are in need of similar improvement and we realize that the hope of satisfactory early improvement of thousands upon thousands of miles of local roads depends solely upon the prompt development of suitable low cost surfaces.

THE BUREAU'S INTEREST IN LOW COST ROADS

The problem now presented by these local roads is much the same as that which thirty years ago was presented by the far more limited mileage of main roads. With the general increase in traffic density that has followed everywhere the mounting motor vehicle registration, we now find these local roads subjected to a traffic as heavy as that which years ago suggested the use of bituminous materials in the improvement of the main roads. The difference is that where thirty years ago the problem was to improve some tens of thousands of miles, that which now confronts the local authorities involves the improvement of hundreds of thousands of miles.

The Bureau's first active interest in experiments looking to the development of methods of low cost surfacing using bituminous materials was an outgrowth of its experience with roads built in the national forests under its direct supervision. When traffic on these roads was considerably lighter than it now is we found the construction of a surface of finely crushed rock or gravel an adequate provision for year-round service. A similar type of surface had been adopted by a number of the western states and a rather considerable mileage had been built when, some five or six years ago, it became apparent that traffic had already increased to a point which would demand that something be done immediately to lay the dust and reduce the heavy loss of surfacing material that was taking place.

The states of Oregon and California took the lead in the experimental use of petroleum oils by various methods to remedy the situation and when their effects had already shown some considerable promise of success, the Bureau joined with the California department in an investigation of the various methods that had been tried with a view to ascertaining what methods, or combinations of methods and materials, might be expected to afford the greatest measure of relief. The results of the investigation were published in 1927 in the Bureau's magazine, *Public Roads*, and in a special bulletin of the California department.

At about the same time the Bureau was also engaged with the Highway Commission of South Carolina in experiments to develop the possi-

bilities of bituminous surface treatment of topsoil roads, and the first report of these experiments, which were distinctly promising, was also published in 1927.

So much the Bureau had done when Mr. James made his recommendation to the industry at the Seventh Annual Asphalt Paving Conference in 1928. The suggestion met with immediate response and in March of the present year a joint technical committee was created to represent the industry and the Bureau in planning and carrying out a comprehensive study of all of the various methods which had by that time been developed in various parts of the country.

LIMITATIONS OF COOPERATIVE RESEARCH

It was agreed to limit the scope of the investigation to the study of the various newer methods of construction or treatment involving bituminous materials designed to produce a dustless surface, resistant to light traffic and less expensive than standard penetration macadam. This would include the various methods of surface treatment of sand-clay, topsoil, gravel, stone and other materials, sand-asphalt mixtures and in-place mixtures of stone, gravel, sand, etc., with all types of asphaltic oils, fluid residuals, cut-backs and emulsions or heavier materials where necessary.

Four principal lines of investigation were projected as follows:

(1) A rapid, but detailed study of the results of all the various methods developed locally in many parts of the country with a view to ascertaining definitely the merits of each, developing information which if promptly disseminated might be generally useful and practically applicable at once, and eventually leading to a knowledge of the principles involved in the newer methods from which to proceed to their further development.

(2) To study the efficiency of the methods of applying and mixing asphalt and aggregates at present employed, to observe the operation of machinery and equipment in detail, and eventually to suggest modifications in equipment and methods which might result in physical and economic improvements of construction methods.

(3) To analyze the asphaltic materials actually used in work done to date and all available materials which might be used with a view to the development of bituminous materials having the characteristics found to be desirable for work of the various classes.

(4) To build and study experimental roads of various types in order to isolate the effects of variables not detectable in the broader field investigations.

ANALYSES TO BE MADE BY BUREAU

In the first phase of the investigation—the broad field studies—it is proposed to make a detailed analysis of the methods, materials, cost and service of the various types of low cost bituminous surfaces thus far developed in various localities, both by the observation of general results obtained and by the more particular study of representative sections of each type of construction with regard to which a more or less complete history is available.

The types to be studied will include sand-clay and topsoil surface treatments in the southeastern states; sand-asphalt surfaces in Massachusetts, North Carolina and other states; bituminous treatments of clay roads in Illinois and elsewhere; the retread method in Indiana and somewhat similar treatments of stone roads in other states; the so-called blotter treatment of gravel roads in Minnesota and adjacent states; oiled sand roads in California, Nevada, Nebraska and elsewhere, and the mixed-in-place treatment of fine crushed-rock-and-gravel surfaces which has reached its highest development in the far western states.

NATURE OF STUDIES ALREADY MADE

Studies have already been made of surface treatments of sand-clay and topsoil roads in Florida and South Carolina; of oil treatments of clay roads in Illinois, and of the retread method in Indiana. The data gathered in the field by engineers of the Bureau, the Asphalt Association and the respective states are in course of analysis at the present time and it is expected that the first reports dealing with these three types will be published very shortly. An indication of the progress that has been made and of the general character of the information obtained will be presented by Mr. Pauls later in this morning's session.

The studies of the efficiency of construction methods and equipment, which constitutes the second phase of the investigation are being conducted by the Bureau with the advice and assistance of the Asphalt Association. These studies are similar in their general aims and methods to studies previously made by the Bureau in the fields of grading and concrete and bituminous pavement construction, and it is hoped that they will produce information of as great value as these other studies have brought out. They have been in progress on a number of selected projects employing equipment and methods of various types for several months, but as yet it is not possible to present any definite results or conclusions.

The third phase of the investigation—that involving a study and analysis of the available bituminous materials—is the particular responsibility of the industry and will doubtless be dealt with at length by Mr. Hubbard in his paper this morning.

COOPERATION WITH OTHER AGENCIES

The fourth phase, involving the construction and study of experimental roads, has also been begun and will be actively prosecuted mainly by the Bureau of Public Roads in cooperation with several of the state highway departments, but always with the active assistance and advice of representatives of the Asphalt Association.

Three such detailed experiments are now in progress; the first a continuation of the surface treatments of top-soil in South Carolina; the second, a series of experiments in California involving the treatment of fine crushed rock and gravel surfaces with several types of bituminous materials by methods of surface treatment and mixing in place, and the third a series of experiments in the treatment of sandy soil with various asphaltic materials. The location of these experiments is the sand-hill section of Nebraska.

The South Carolina experiments have been conducted in cooperation with the State Highway Commission. Four experimental roads have been built in as many counties since 1925; but the first, a road in Anderson County, having served its purpose, is no longer under observation by the Bureau. A report of the experiments on this road was published in the November, 1927, issue of "*Public Roads*."

The other three projects in South Carolina are under current observation and constitute sources of information for the cooperative investigation. These are in Spartanburg, Horry and Berkeley counties.

EXPERIMENTAL ROADS IN SOUTH CAROLINA

The Spartanburg County project is located on State Route 19, beginning at the southern city limits of Inman and extending north to the state line. There are five experimental sections aggregating 8 miles in length, on each of which the topsoil surface was given a double surface treatment, the variables being the bituminous materials and the mineral covering. On all sections the priming material was applied at the rate of $\frac{1}{4}$ gallon per square yard and the second application at the rate of $\frac{1}{3}$ gallon per square yard. On the first and fourth sections the primer was a tar of 8 to 13 specific viscosity of 40° C. and the second coat was of hot tar, the variables being the cover material which consisted of slag and stone, both graded from $\frac{1}{4}$ to 1 inch. On the second section the primer was a cut-back oil and the second application was a hot asphalt of 150 to 200 penetration. The cover was $\frac{1}{4}$ to 1 inch stone. The third section had a prime of cut-back oil and a second coat of hot tar with covering of stone and dolomite chats, and the fifth section a prime of tar and a second coat of hot asphalt of 150 to 200 penetration, with covering of stone.

These experimental sections were built in 1925 and have since been under continuous maintenance and observation. A report of all available data up to the summer of 1927 was published in "*Public Roads*" for November of that year.

EXPERIMENTS IN HORRY COUNTY

The Horry County experiments were conducted on a section of State Route 38, 20.6 miles in length, between Conway and Galivants Ferry. This project, which was a test of mixed-in-place topsoil surfaces, was constructed in 1927. There are eight experimental sections, each in turn divided into subsections to a total of 29. Two of the sections, covering a total length of 12,700 feet, were planned to be maintained by machine. In these, four slow-curing oils were used in the mixing process and no seal coat was applied. The four oils used on these sections were as follows:

Section 3, 5000 feet, No. 5 road oil.

Section 4A, 2600 feet, No. 5 road oil with pressure still tar.

Section 4B, 2600 feet, No. 6 road oil with pressure still tar.

Section 4C, 2500 feet, flux oil with pressure still tar.

The remainder of the sections were designed for patrol maintenance by patching. In these, various grades of quick-drying asphalts and tars were used in the mixed base and single or double surface treatments,

with cover material of sand, pea gravel, crushed stone and treated soil. One section, No. 8, had only a surface treatment. The base was not mixed. It was divided into two sub-sections on one of which the primer was 85-100 penetration asphalt cut-back with naphtha and on the other tar of 8 to 13 specific viscosity. On both, the seal coat was 150-200 penetration asphalt, applied hot. The prime applications were in the amount of approximately a half-gallon and the seal at the rate of $\frac{3}{8}$ gallon per square yard. The cover in each case was $1\frac{1}{4}$ to $\frac{1}{4}$ inch stone in the amount of 60 pounds per square yard.

THE BERKELEY COUNTY TESTS

On all other sections the base was mixed with bituminous material, consisting of cut-backs of asphalt of 85-100, 100-120, and 150-180 penetration, and tar of 18-25 specific viscosity, and to these mixed bases were added surface treatments of various materials, the combinations being too complex to enumerate.

As previously stated, these sections were built in 1927. Since that time complete records of traffic, maintenance and all pertinent information have been kept but no report has been published. The analysis of the results obtained will supply important data for consideration in the cooperative investigation.

The third of the current South Carolina experiments is located in Berkeley County. The construction was completed during the past summer. In these experiments, which have been conducted on $4\frac{1}{2}$ miles of State Route 46, near Moncks Corner, we have experimented with stone surfaces laid on sand-clay and marl bases, there being $2\frac{1}{2}$ miles of the former and 2 miles of the latter. Except for the length of the sections and the surfaces applied over the two types of base were of the same five kinds. Four of the surfaces on each type of base were mixed in place and the fifth was surface treated.

The objects of the surface experiments were to determine the relative value of mixed-in-place and surface treated surfaces, and to test the practicability of using variously graded mineral aggregates with cut-back asphalts in the mixed-in-place method of construction. Consequently each of the mixed-in-place sections involves a different gradation and size of mineral aggregate. The first experiment was divided into two sections in one of which the bituminous material was a 60-70 penetration asphalt, cut back with 25 to 30 per cent of heavy naphtha, and in the other an 85-100 penetration asphalt, also cut back with 25 to 30 per cent of heavy naphtha. In the other three mixed-in-place experiments the 85-100 penetration material was used.

THE CALIFORNIA EXPERIMENTAL ROAD

The surface treated section on the marl base was treated with the same 85-100 penetration material in the amount of about a half-gallon to the square yard and the same treatment was applied to a portion of the section on sand-clay base, the remainder of the section being treated with Colas.

The California experiments represent an effort to test, under identical conditions, the relative values of cut-back asphalts, emulsions and so-

called fuel oils for surface treatment and mix-in-place construction on fine crushed rock and gravel surfaces. These experimental surfaces have been constructed during the past summer on a section of road about 10 miles in length near Truckee, the Bureau cooperating with the Division of Highways of the California Department of Public Works.

The section of road involved had previously been surfaced in 1927 with mixed-in-place crushed rock. The old surface had become inadequate and it was to be strengthened by addition of a new compacted depth of 3 inches of stone. Advantage was taken of this occasion to try the various bituminous materials and methods of construction.

SAND-OIL ROAD EXPERIMENTS IN NEBRASKA

The project includes a total of 20 experimental sections in all but two of which the mineral material is fine crushed rock, the exceptional sections being fine crushed gravel. The bituminous treatments consisted of in-place mixtures of fuel oil, kerosene cut-backs, and emulsions, and surface treatments with fuel oil, a heavy road oil, asphalt of 150-200 penetration, and two emulsified asphalts from different sources.

The Nebraska experiments, which have also been constructed during the past summer are located on Federal Aid Project 313-A, a stretch of road about $9\frac{1}{2}$ miles in length, beginning at the town of O'Neill and running south toward Bartlett. The soil at this point is characteristic of the sandy soils which occur over a large area of the State of Nebraska.

The entire project, which was constructed in cooperation with the state highway authorities, is divided into nine sections, each approximately one mile in length. The work just completed consisted of the construction of a mixed sand-oil surface of 4 inches compacted depth over the entire length of the road. In this work the only variable was the bituminous material, of which there were three types, each applied to three sections. On sections 1, 2 and 3 the material used was road oil of 60-70 per cent asphalt of 100 penetration; on sections 4, 5 and 6 an oil of 70-80 per cent asphalt of 100 penetration was used, and on sections 7, 8 and 9 the material used was a soft asphalt cement, cut back with a slowly volatile solvent. Each of these materials was applied at the rate of from 3 to 4 gallons per square yard.

Next summer, when the mixed surfaces have become thoroughly compacted, it is proposed to surface treat a number of the sections as follows:

OBJECTS SOUGHT IN THE STUDIES

Experiments Nos. 1, 4 and 7 are to be left untreated. Experiment No. 2 is to be given a light application of the same oil that was used in the mix and covered as needed with the sandy soil. Experiment No. 3 is to be given a light application of a soft asphalt cement and covered as needed with the soil. Experiment No. 5 is to be surface treated with the same oil that was used in the mix and covered with the soil. Experiment No. 6 will have a treatment with the soft asphalt cement and sandy soil. Experiment No. 8 will be given the same treatment as No. 6, and Experiment No. 9 will be treated with the same material as Nos. 6 and 8, but will be covered with gravel.

From this necessarily sketchy outline of the cooperative researches to

be carried out jointly by the industry and the Bureau, it will be seen that the plan contemplates:

First, a broad study of a large mileage of low cost surface of the various types as constructed in all sections of the United States, with more detailed observation of certain representative sections of each type, for which the necessary historical data are available. These studies, which have been completed with respect to surface treatments of topsoil and sand clay in the states of South Carolina and Florida, with respect to oiled clay roads in Illinois, and the retread method in Indiana, are being made by the district representatives of the Bureau and representatives of the Asphalt Association and several of the companies.

The second phase is the study of the efficiency of methods and equipment in use, the aim of which is eventually to suggest improvement in equipment and methods. This part of the work is being done by the Bureau with only incidental assistance from the Asphalt Association. The third phase is the study and analysis of bituminous materials, which is the special province of the Asphalt Association.

And finally, as a fourth phase, there are the experimental roads on which we are depending for the intensive study of materials and methods which will serve to supplement with detailed analysis the general observations made on the large mileage covered in the rapid field studies which constitute the first phase.

CHAIRMAN A. J. WEDEKING: You have heard something of the work the Bureau is doing in its investigation of the various road problems of the country and its efforts to serve the people in their desire to get a road that will serve their purpose at a low cost. The various road industries have been cooperating with the public agencies in furthering investigations that would bring about the results which we are all trying to obtain. We have with us this afternoon a representative of the asphalt industry, who will discuss that for our benefit. I am pleased to introduce to you Mr. Prevost Hubbard, chemical engineer of the Asphalt Association, New York, who will now address you.

Cooperative Research and Standardization of Low Cost Road Improvement

Industry Participation

By Prevost Hubbard, New York, N. Y.

Chemical Engineer, The Asphalt Association

In the excellent paper just presented by Mr. Fairbank the general scheme of cooperative research and standardization of low cost road improvement has been clearly outlined, and participation by the Federal Government has been discussed in some detail. Mr. Pauls will shortly describe the progress already made in joint field studies of a number of types of low cost roads. The present paper therefore will be limited to

a brief discussion of the part to be played by the asphalt industry in developing and perfecting bituminous products for the different types of low cost roads and their various methods of treatment or construction.

Since its organization and until the beginning of the present year the scope of activity of the Asphalt Association had been limited almost exclusively to the use of asphalt cements in the construction and maintenance of pavements of types as high or higher than asphalt macadam, and but little attention had been directed to the development and use of asphaltic products of softer or more fluid consistency. Although many of the producing companies for years had been developing and marketing fluid products, to meet such state and other highway specifications as were found economically to be possible for the individual producer, the asphalt industry as a whole had come to no understanding as to just what properties in asphaltic products were required for successful results in what apparently has developed into a bewildering multiplicity of types and methods of use.

EXPERIMENTAL STATUS OF LOW COST ROAD IMPROVEMENT

The present era of low cost road improvement is largely one of experimentation, and very properly so if the highway engineer is to develop economical methods and types best adapted to meet the particular conditions with which he is confronted. As a rule, he is familiar with the details and requirements of higher types of pavements, the construction of which until recently has occupied most of his attention. In his more recent and more experimental low cost road work, however, he is apt to be handicapped considerably by lack of detailed information as to just what possibilities exist in connection with the use of asphaltic products and just how best to describe or specify the particular products which he wishes to secure. It is here that the asphalt industry as a whole should be of service to him. And it should also be to the advantage of the industry collectively to furnish such assistance, not only with the idea of extending its market for asphaltic products but to weed out the many unnecessary requirements in existing specifications which not only curtail source of supply but, through overlapping and slight variation, often make it necessary for a single producer to carry a number of stocks for identically the same use by different consumers, where a single grade of material would serve equally well for all.

WHAT THE INDUSTRY IS DOING

Since the organization of the joint technical committee in March of this year and the adoption of the general plan of cooperative investigation described by Mr. Fairbank, representatives of the asphalt industry have not only participated in the study of certain selected types but have been endeavoring, through personal inspection of thousands of miles of highway in various parts of the country, to form a composite picture of the nation-wide effort to develop improved low cost roads and to assemble as much information as possible in connection with all asphaltic products at present available for such work. Such preliminary steps are essential to the rational development and improvement of these products.

Substantial expansion of existing personnel and research facilities are necessary to the rapid progress which is needed and the movement should receive the active support of the entire industry. The responsibility of the industry is not only very definite but inclusive in its application and urgent in its character. The requirements of engineers in this broad field can be far less satisfactorily worked out by contact with individual producers than with the entire industry and the moral support of engineers in urging the active cooperation of those producers not now identified with the movement will be to their own interest and that of the taxpayers whom they represent.

At the present time the speaker can only report progress in collecting information on available asphaltic materials, their relation to existing specifications and certain needed improvements in products to be used for specific purposes. The behavior of certain asphaltic material in combination or contact with various soil types and mineral aggregates requires considerable systematic study not only in the field but in the laboratory before all of the existing problems are solved.

During the past eight months, the speaker has inspected several thousand miles of low cost road work of various classes. Many of the existing types as yet have not been included in this survey but statement of certain tentative deductions at which he has arrived relative to asphaltic products for such work may not be out of place at this point.

OBSERVATIONS ON MIXED-IN-PLACE METHODS

In the construction of mixed-in-place soil, gravel and similar traffic compressed roads, successful results are obtained only with a mineral aggregate of such character as would produce an entirely serviceable road, providing a suitable moisture content could be continuously maintained. In such classes of roads, the bituminous material serves primarily to replace this optimum moisture content and maintain the compressed mineral aggregate in its state of maximum stability. The natural stability of the aggregate will be increased by the adhesive strength developed by the bituminous material but no bituminous material which can be applied successfully by the mixed-in-place method will, in itself, produce the necessary stability if the mineral aggregate itself is not inherently stable.

In arid or semi-arid localities, waterproofing the road surface is of minor importance and satisfactory results often may be secured with a bituminous product containing a relatively low percentage of asphalt or one which will not develop its asphalt content to the extent of producing a water resistant mixture. Such products, which may be termed non-curing road oils, are entirely unsuited for similar work in localities where, because of the extent of rainfall, waterproofing of the surface becomes a major consideration. In these localities they will not prevent the mineral aggregate from taking up sufficient water to produce an unstable condition and, at the same time, are apt to emulsify with the absorbed water and the fine portion of the mineral aggregate to produce a very unsatisfactory surface. Development of the asphalt base in place to meet such conditions is essential and the product should be of such nature as to develop this base as quickly as possible after thorough

consolidation of the road has been secured. Slow curing cut-back asphalts are indicated as the proper class of bituminous material to be used under such conditions and even then surface treatment with a soft asphalt cement to waterproof the underlying structure may be considered as a desirable expedient.

In these mixed-in-place types, considerable differences of opinion have been found between various engineers as to the proper amount of bituminous material to incorporate with the mineral aggregate. It is believed that the same laws which apply to hot-mix paving mixtures are applicable to the mixed-in-place aggregates in so far as the maximum percentage of bituminous material is concerned. In other words, the percentage of voids in the compressed mineral aggregate sets the maximum limit for the amount of bituminous material to be used and any over-filling of the voids will greatly reduce the stability of the mixture. On the other hand, a much lower minimum amount of bituminous material often may be used than would be permissible in the hot mixed types, particularly in arid regions or when a bituminous seal coat is also used.

OBSERVATIONS ON SURFACE TREATMENT METHODS

Except for the purpose of dust prevention only, all surface treatment should be made with the idea of waterproofing the underlying road structure, which of course must be sufficiently stable, when waterproof, to prevent the bituminous mat or carpet from breaking through under traffic loads. The asphaltic product used for this purpose should be of sufficient viscosity or consistency to produce, with the mineral cover, a mat which will not shove under traffic, but it should not be so hard as to become brittle and subject to rapid abrasion. For mat construction on any type of road, a soft asphalt cement of, say, between 150 and 300 penetration, seems to be the most durable. Where it is desired, as in maintenance work, to keep the thickness of the new mat to a minimum, or where an old mat is merely to be rejuvenated, a cut-back asphalt cement containing a readily volatile solvent is probably the most suitable material to use. Neither this type of cut-back nor a soft asphalt cement is best suited for initial treatment of a surface which cannot be thoroughly freed from dust or extremely fine aggregate, as neither has the requisite penetrating properties to attach themselves to the underlying surface at all points.

ASPHALTIC PRODUCTS REQUIRED FOR LOW COST ROADS

For the initial treatment of dusty surfaces, or those containing an appreciable amount of fine mineral aggregate, the use of a priming oil is highly desirable if not absolutely essential. Application of such primer, however, should be followed with a heavier or more viscous product. The attention of the asphalt industry may well be directed to the production of an efficient priming oil, as many of the products so far used for this purpose have not proved as satisfactory as desirable. The priming oil should be of very low viscosity in order to penetrate the road surface and a cut-back asphalt will be suitable for this purpose if the distillate used is not as rapidly volatile as the usual grades of gasoline and if it is a good solvent for the asphalt base.

It would seem that the following four basic types of asphaltic products should meet most of the requirements for low cost road construction or treatment:

- (1) A priming oil of low viscosity for cold application, consisting of a relatively hard asphalt cement, cut back with a kerosene type of distillate.
- (2) A slow curing oil of medium viscosity which ordinarily would be applied after warming to moderate temperature and consisting of a relatively soft asphalt cement, cut back with a kerosene type of distillate, or in certain cases of residual oils or blends possessing similar properties.
- (3) A rapid curing oil of fairly low viscosity for cold or slightly warm application consisting of a paving asphalt, cut back with a gasoline type of distillate.
- (4) A very soft asphalt cement of between 150 and 300 penetration.

The number of grades of each of these four types which might be required is at present problematical. Probably a single grade of priming oil, not over three grades of slow curing oil, two grades of rapid curing oil and two grades of soft asphalt cement would be sufficient. Emulsified asphalts suitable for use in place of certain of these products would, of course, be considered as a separate class.

SIMPLIFICATION OF SPECIFICATIONS FOR ASPHALTIC PRODUCTS

A study of existing specifications of the state highway departments shows not only an unnecessarily large number of individual products, many of which differ but very slightly in their characteristics, but the specified tests for these products is unnecessarily large, without taking into consideration the great variation in test limits specified. This all tends to create a confusion from which it is difficult to separate the essentials from the nonessentials. Thus between fifty and sixty different test requirements (not test limits) have already been listed from the state specifications so far tabulated. Viscosities with three different instruments and at five different temperatures have been used together with seven volatilization tests and a number of distillation tests by different methods. Without enumerating all of the tests, it is believed that those mentioned will illustrate the great desirability of a simplification of specifications.

Criticism of an existing state of affairs is not of much value unless some remedy is suggested. As the result of observations to date, the speaker feels that a comparatively few tests will serve to determine all essential characteristics in the asphaltic products used for low cost road construction and treatment. Test limits would, of course, vary for the different grades of such products. For the four general classes of materials previously enumerated, it is believed that the following tests will provide all necessary information:

- (1) Flash point for all four products.
- (2) Specific Viscosity Engler at 77° F. for priming oils.

- (3) Specific Viscosity Engler at 122° F. for slow curing and rapid curing oils.
- (4) Penetration at 77° F. for the soft asphalt cement.
- (5) Distillation test with cuts at three temperatures for all products but the asphalt cement; with float test or penetration test specified for the residue from distillation.
- (6) Volatilization test for the asphalt cement; with penetration of residue specified.
- (7) Solubility in carbon-disulphide for all products.

Thus for all products a total of not over eight tests, and for any individual material, of not over seven specification requirements is suggested.

After all of the data relative to the characteristics of available asphaltic products and the specifications under which they are furnished at present have been assembled, it is believed that rapid progress should be made in the simplification of specifications. This work, however, will require the friendly cooperation of engineers and chemists responsible for the preparation and adoption of such specifications.

CHAIRMAN WEDEKING: Up until today, I have been under the impression, for all these many years of my life, that the claim that King Nebuchadnezzar had to fame was that he was responsible for the phrase "the handwriting on the wall," but looking over to my left I see that he built the first asphalt paved street, and that is probably the reason he lived in history. Going back to the Scriptures for a little bit of introductory matter for the next speaker, I would say that one of the greatest field men of his time was also named Paul, and I was told on good authority this morning that he was the forerunner of all the Pauls now living, and that the Pauls about to address you at this time can trace his lineage back to that other great field man who was as energetic and as forceful in proclaiming the doctrine of Christianity as is his descendant in preaching the gospel of good roads. I am mighty glad to introduce to you this afternoon Mr. J. T. Pauls, highway engineer, Division of Tests, U. S. Bureau of Public Roads.

Progress in Field Studies of Bituminous Treatment for Low Cost Roads

By J. T. Pauls, Washington, D. C.

Senior Highway Engineer, U. S. Bureau of Public Roads

A determined effort is being made by the asphalt industry, various states and the Bureau of Public Roads toward developing satisfactory low cost bituminous treatments for the secondary roads. An attempt will be made in this paper to indicate the scope and progress of this work on several types of road by describing briefly some of the field experiments conducted during the last few years.

Considerable attention has been given to the bituminous surface treatment of topsoil and sand-clay roads. Thousands of miles of these roads have been built in the southeastern states with lesser mileage in other sections. The topsoil material is generally a natural mixture of sand and clay found extensively in the large areas of the South Atlantic states where it is the top foot or more of surface soil and is generally used as it comes stripped from the field. The construction of a sand-clay surfacing, on the other hand, generally requires the addition of one or the other material.

While these roads are vastly superior to the ordinary graded earth roads, they soften during long periods of wet weather and become very dusty in dry weather. Also, the cost of maintenance becomes very high as traffic increases above 400 or 500 vehicles per day. An attempt to improve them by surface treatment was first made by the South Carolina Highway Department on a 4 or 5 mile stretch during 1924. The results of this early work appeared so successful that in 1925 an additional 8 miles were built by South Carolina in cooperation with the Bureau of Public Roads as an experimental project. These experiments and the state work proved so successful that since that time several thousand miles of these roads have been surface treated throughout the southeastern states.

EXPERIMENTS IN FLORIDA AND SOUTH CAROLINA

It recently was felt that still greater possibilities existed for work of this type, not only in this portion of the country but elsewhere, and that further study of materials and methods would develop improvements which would eliminate chances of failure that now exist. For this reason the Asphalt Association and the Bureau of Public Roads co-operated in making a field survey of surface treated roads in South Carolina and Florida. Some of the important features of this type of construction, as determined from this survey and from the results of the experiments, will be given. A report on the 1925 experiments is given in the November, 1927, issue of *Public Roads* and a report of the survey will soon be published.

In the construction of this type of treatment careful preparation of the sand-clay or top-soil is necessary before applying the surface treatment. Any defects or irregularities in the surface of the base will be reflected in the surface treatment. The untreated base should be smooth, compacted and well bonded. To secure this condition it is usually necessary, shortly before surface treating, to do a considerable amount of machine work such as scarifying, harrowing, blading and dragging. The following steps generally are taken in surface treating roads of this type:

- (1) Thorough sweeping to remove all loose particles and dust.
- (2) Application of a prime coat of about $1/3$ gallon of tar or asphaltic oil of sufficiently low viscosity to penetrate well into the surface.
- (3) Application of $1/3$ to $1/2$ gallon of an asphaltic product of relative high viscosity.
- (4) Application of mineral aggregate cover, consisting of broken stone, slag or gravel passing a 1 in. screen which, after broom-

ing and rolling, combines with the second application of bituminous material to produce a thin wearing course knitted to and overlying the old sand-clay or topsoil road.

- (5) Frequently a light second application of the high viscosity asphalt material is applied and covered with fine mineral aggregate thoroughly to seal the surface, if the surface, after a few months' traffic, does not have the desired degree of water-proofing.

APPLYING THE PRIMING TREATMENT

The purpose of the priming treatment is to harden and moisture-proof the upper portion of the base and produce a surface to which the heavy non-penetrating bituminous material will adhere. The primer should be of sufficiently low viscosity to be absorbed readily by the sand-clay or topsoil surface and not dry or harden so rapidly as to produce a mat before it has had an opportunity to penetrate. Light tars of 8 to 13 viscosity at 104° F. have been used extensively and have been found to penetrate and harden more rapidly than the asphaltic products so far used. Asphalt cement, cut back with a light volatile oil, such as kerosene, should prove entirely satisfactory for use as a primer. The proper amount of primer should be that which will be readily absorbed in about 24 hours. There is no advantage in using an excess. The quantity required may vary from 0.2 to 0.35 gal. per sq. yd.

The mat forming material which is applied to the prime surface should possess as much body and adhesiveness as possible. Experience has shown that soft asphalt cement of between 100 and 300 penetration is most satisfactory from the standpoint of durability and resistance to shoving of the mat. The quantity of heavy asphalt material required will range from 1/3 to 1/2 gal. per sq. yd. depending on the size and quantity of mineral aggregate used. The material should be applied between 250 and 325° F. and extreme care should be exerted to secure uniform distribution without breaks in the bituminous film.

Mineral aggregate for cover should consist of hard fragments free from dust and in size from 3/4 to 1/4 in. With relative soft and more friable material a slightly larger size from 1 1/4 to 1/4 in. would be desirable, crushed fragments being preferable to round pebbles.

SEAL COAT MAY BE REQUIRED

The amount of covering will depend on the quantity of asphaltic material and the size of the aggregate. Sufficient cover should be used to prevent bleeding of the mat, but care should be taken not to use an excess in amount so as to produce a mixture which will wear rapidly under traffic. It is much better to use insufficient cover material at first, and then more as required later, than to overload bituminous material at first. Generally, 10 pounds of mineral aggregate for each 0.1 gal. of bituminous material may be taken as the approximate quantity of cover required.

Uniform distribution of the aggregate is very important, both for stability of the mat and good riding quality. The present practice of spreading the aggregate is either by mechanical spreaders or by shovel from stock piles placed at suitable intervals along the road. Light blad-

ing, dragging or brooming before rolling proves advantageous in producing a surface with good riding qualities.

Immediately after spreading the cover it should be rolled with a 5 to 7½ ton roller until thoroughly compacted and bonded with bituminous material. The amount of rolling should be controlled so as not to produce excessive crushing of the aggregate. After the treatment has been in service for some time it may require a seal coat. South Carolina usually applies a seal treatment as a precautionary measure before the winter following construction.

The selection of material to be used in these subsequent treatments depends on the results desired. If it is intended to enliven the surface and prevent raveling of an already heavy mat, a slight cold application of a cut-back material, containing a readily volatile distillate, with small size mineral aggregate, should be used. If it is necessary to strengthen the old surface mat by adding thickness, a heavier bituminous material, such as is used in original construction, is applied hot.

For the light treatment an asphalt cement of not over 200 penetration, cut back to a low viscosity with a gasoline type of distillate, will be satisfactory. This material should be applied at the rate of about ¼ gal. per sq. yd. and covered with clean crushed aggregate ranging in size from ⅝ to ¼ in. Good results from surface treatments depend on careful and intelligent maintenance applied promptly when needed. Patrol maintenance to detect and correct failures as they occur is important. In addition, maintenance retreatments are required, at intervals of 2 to 3 years, either of light seal or heavier treatment to thicken or smooth the wearing surface.

COSTS FOUND TO VARY WITH CONDITIONS

The construction and maintenance costs vary naturally with local conditions. The following figures give the average cost obtained from a large number of roads:

(1) Construction costs per mile:

Sand-clay or topsoil, 20 ft. by 6 in.....	\$1,500 to \$3,000
Prime and heavy application with cover complete..	1,800 to 2,500
Seal course treatment.....	500 to 1,000

(2) Maintenance cost per mile per month:

First year—

Surface treatment only.....	\$15 to \$60
Shoulders and ditches.....	15 to 50

Second year—

Surface treatment only.....	5 to 20
Shoulders and ditches.....	0 to 20

The Spartanburg surface treatment experiments which were built in 1925 and which are now in excellent condition and carrying approximately 1500 vehicles per day have cost as follows:

(1) Cost per mile of original surface treatment exclusive of seal	\$1,695 to \$2,425
(2) Average yearly cost of maintenance including seal and retreatments during the four years since construction, approximately	300 to 550

Another series of recent experiments in bituminous treatment of low cost roads that might well be mentioned are those carried on by the South Carolina Highway Department and the Bureau in Berkeley and Horry counties, South Carolina. Soil over a large portion of the coastal area is very sandy and has insufficient binder to make possible the construction of satisfactory sand-clay roads. The purpose of the experiments constructed during 1927 in Horry County was to develop satisfactory bituminous soil mixtures both for surface treatment and machine maintenance.

MATERIALS USED FOR SURFACE TREATMENT

The procedure in the construction was to scarify the road surface, pulverize, add bituminous material and mix in place, using disks and blade machines, afterward compacting with traffic while at the same time blading or dragging lightly to eliminate irregularities as they developed in the surface during early compaction.

Several types and grades of bituminous material were used in the mix which included the following:

- (1) Refined coal tar for cold application with specific viscosity of 18 to 25 at 40° C.
- (2) Asphalts of 85-100, 100-120 and 150-180 penetration, cut back with heavy naphtha to suitable viscosity for cold application.

The above materials were used on those sections designed to receive surface treatment. In addition, there were four different grades of slow drying road oils used on sections designed for machine maintenance. These sections were mixed to a compacted depth of 3 in. while those to receive surface treatment were made to a depth of 2 in. Both the cut-backs given above and hot application asphalts and tars were used in surface treatments of the mix.

These experiments have not been in service for a sufficient length of time to permit the drawing of definite conclusions as to the respective values of the materials and type of treatment. However, it is evident from their behavior up to this time that a satisfactory base for surface treatment can be obtained by mixing such cold application asphalts, road oils and tars as are given above, with fine grain soil having as much as 30 per cent of silt and clay. An oil mix with this type of soil, including a large amount of silt and clay, will not resist raveling and peeling under traffic and will require a surface treatment. It is also probable that with this type of soil a slower drying cut-back such as the kerosene type would have an advantage over the quicker drying material used.

OBJECTS OF THE EXPERIMENTS

The object of the experiments which have been built this year in Berkeley County is to determine: (1) comparative values of sand-clay and marl for base construction with bituminous surfacing; (2) the relative value of a mixed-in-place surfacing compared with the surface treatment type of construction, and (3) the practicability of using variously graded mineral aggregates with cut-back asphalt, tars and emulsions in the mixed-in-place method of construction.

No difficulty was encountered in the construction of these sections. The stone sections were made to give a compacted thickness of 2 in. The

aggregate in the fine graded mix ranged in size from $1\frac{1}{2}$ in. to $\frac{1}{4}$ in. with the addition of about 30 per cent of fines from $\frac{1}{4}$ to that passing 200 mesh. Precaution was taken to eliminate segregation by not adding the fine material until a first application of bituminous material had been applied to the spread coarse stone. The steps in construction were as follows:

- (1) Spread coarse stone.
- (2) Apply first application of bituminous material.
- (3) Spread fine aggregate.
- (4) Apply second application bituminous material.
- (5) Mix as required with blade or drag.
- (6) Roll.
- (7) Seal if necessary.

In the construction of the coarse mix section, $1\frac{1}{4}$ in. to $\frac{1}{4}$ in. stone was used. The procedure was similar except a final keystone cover was applied, followed by rolling and seal.

NATURE OF CALIFORNIA EXPERIMENTS

Two other series of experiments which have been under construction during the last summer, as cooperative experiments between the Bureau and the states in the bituminous treatment of low cost roads, are those near O'Neill, Nebraska, and Truckee, California.

The purpose of the work at O'Neill is to develop satisfactory surfacing by mixing in place various grades of road oils and cut-back asphalts with slow drying distillate of the kerosene type to the blow-sand soil such as predominates over a large area of this state. The plan also calls for various types of light surface treatments on portions of the mixed sections in order that comparisons may be obtained between the surfaced and unsurfaced mixes.

The following is typical of the grading of the soil on this project and in this portion of the country:

Passing 10	Retained 20 mesh	.....	1.2%	by weight
Passing 20	Retained 30 mesh	.....	2.0%	by weight
Passing 30	Retained 40 mesh	.....	9.1%	by weight
Passing 40	Retained 50 mesh	.....	21.8%	by weight
Passing 50	Retained 80 mesh	.....	44.5%	by weight
Passing 80	Retained 100 mesh	.....	10.5%	by weight
Passing 100	Retained 200 mesh	.....	9.5%	by weight
Passing 200	.....	.....	1.4%	by weight

Preliminary laboratory tests made on oil mixes with this soil showed substantial increased stability with the addition of 3 per cent of lime-stone dust. In the design of the sections 3 per cent of dust accordingly was added to a portion of each experiment. The plan of construction was to mix in place in two layers to give a compacted depth of 4 in. using approximately 4 gallons of bituminous material per sq. yd.

CRUSHED STONE AND MIXED-IN-PLACE METHOD

The California experiments are a study of the suitability of the various types of bituminous materials when used with crushed stone and gravel aggregate in the mixed-in-place type of construction and in various types of surface treatment of crushed stone and macadam bases. The oil mix

sections were completed this summer while the surface treatment work on the stone macadam will be completed early next year.

The plan of construction of the bituminous mixed-in-place sections was briefly as follows: Aggregate, sufficient to give compacted depth of 3 in. was placed in windrows along the edge until the time of mixing when it was spread previous to applying the bituminous material. To facilitate the handling of traffic one windrow was mixed and replaced to the edge of the road until the other had been mixed, at which time both windrows were combined and spread. Compaction was obtained by traffic on the road oil sections, while on the heavier asphalt mixes some rolling proved desirable.

The following bituminous materials were used in the mixed sections:

- (1) 60-70 per cent road oil of 55-80 specific viscosity at 50° C.
- (2) 70-80 per cent road oil of 55-80 specific viscosity at 50° C.
- (3) 94 + per cent road oil, cut back with kerosene to a specific viscosity of 55-80.
- (4) 100-120 penetration asphalt, cut back with kerosene as above.
- (5) 94+ road oil emulsion.
- (6) 100-120 penetration asphalt emulsion.

The aggregates used in the sections were crusher run stone, grading from $\frac{3}{4}$ in. down to 3 per cent of material under 200 mesh, crusher run, to which fines was added bringing the material passing 200 mesh up to 8 or 9 per cent, crushed stone from $\frac{3}{4}$ in. to $\frac{1}{8}$ in. and washed gravel blended with fine crushed gravel to range in size from $\frac{3}{4}$ in. to 4 or 5 per cent passing 200 mesh. The amount of bituminous material used varied with the grading of the aggregate. On the road oil sections the amount varied from about 1.5 to 1.9 gal., and on the cut-back sections a slight increase was used to compensate for some anticipated loss of the solvent.

RESULTS WITH THE USE OF EMULSIONS

In the construction of the sections with emulsion, $\frac{1}{2}$ to $\frac{3}{4}$ gal. of 60-70 road oil was first mixed into the aggregate as a prime, while on one section about 2.0 gal. of water was used instead of the road oil. One and one-half to 2 gal. of emulsion were used in the mix. A portion of each of the sections was sealed after compaction, using about $\frac{1}{4}$ gal. of emulsion and covering with $\frac{1}{4}$ in.- $\frac{1}{8}$ in. crushed stone.

No difficulty was encountered in the construction of the oil or cut-back sections. Emulsions, on the other hand, mixed with difficulty and only partially covered the aggregate. The material seemed to combine with the fines, leaving the larger aggregate uncoated. Persistent rolling after the mix had been spread pressed the asphalt and fines around the coarser material to form some surface bond. However, it was the consensus of opinion on this work that a seal would be necessary to prevent raveling and failure of the surface.

Careful study of the service behavior of the various treatments used in the different experiments, together with the results obtained from the cooperative field studies, should supply information resulting in the use of better methods and more suitable materials.

CHAIRMAN WEDEKING: We will now hear the next paper on "Surface-

Treated Sand-Clay Roads In the Southeast," by a man from the state which sent out notices, not many weeks ago, to the traveling public that it should avoid the roads of Georgia. They must be very efficient down there in the rehabilitation of their roads, because about a week later the invitation was broadcast, "Come down to Georgia." Now we are going to hear from the State Highway Board of Georgia in the person of its asphalt engineer, Mr. B. P. McWhorter, who will address you.

Surface Treated Sand-Clay Roads in Georgia and Florida

By B. P. McWhorter, East Point, Ga.

Asphalt Engineer, State Highway Board of Georgia

In the northwestern part of the State of Florida and the section of Georgia south of the fall line, practically all the roads at one time were surfaced with sand-clay as a wearing surface. As the roads were re-located and graded to the present-day standards of construction a sand-clay surface of selected material invariably was placed on top as a wearing surface until the subgrade became thoroughly settled. Not only did this surfacing answer as a temporary surface but it formed a stable subgrade upon which to lay the more permanent type of surfacing to follow.

It soon became apparent that funds were not available to surface all the graded and improved roads with the so-called permanent surfaces such as concrete or standard asphalt pavements. In order to provide relief for the people using these roads and to protect the investment in the bases, and at the same time provide a hard surface at a nominal cost, experiments were conducted toward surface treating this type of road.

TYPE OF BASES PREFERRED

The sand clays of northern Florida cannot compare in their composition with the high grade sand-clay deposits of Georgia. In Georgia we have excellent deposits of chert in the northwestern part of the state, clay-gravel and topsoils in the central portion and sand-clays and iron oxide silica in the south-central and southwestern portions. Great care should be exercised in the construction of sand-clay bases in order to secure bases characterized by high stability and which are not affected to a great extent by water. Under this category comes the chert deposits, gravel deposits, topsoils and iron oxide silica soils of Georgia. A sand-clay soil of the mechanical composition having high stability must have from 10 to 18 per cent clay, 5 to 15 per cent silt and total sand, 65 to 80 per cent. When coarse material above a No. 10 sieve is added it increases the stability and gradually increases until the full type of gravel slab is reached.

In south-central and southwest Georgia there are large and numerous deposits of iron oxide silica and, from past observations, we believe this

material makes the best base material for surface treating in the state, outside of the lime rock bases. This material is characterized by high stability and makes an excellent wearing surface when not surface treated. It is affected least by water of any of the clay bonded-type bases with the exception of the chert or top soils. The characteristics of the raw materials and quality of binder make it better than any of the bank-run gravel deposits we have. Analysis of the following table shows that this soil contains 15.9 clay, 49.7 per cent coarser than 60 mesh, 34 per cent above 10 mesh and 28 per cent above a $\frac{1}{4}$ mesh.

Sample Number	1	2	3	4	5	6	
Sand ret. 20 mesh	2.7	6.8	4.1	7.2	3.8	7.7	
Passing 20 ret. 60	50.5	48.4	45.5	45.4	37.2	40.6	
Passing 60 ret. 200	26.8	20.0	28.1	25.0	32.8	26.4	
Total sand	80.0	75.2	77.7	77.6	73.8	74.7	
Total silt	7.2	5.8	8.2	7.0	9.4	7.9	
Total clay	12.8	19.0	14.1	15.4	17.4	15.9	av. 15.9
Sand coarser than 60 mesh..	53.2	55.2	49.6	52.6	41.0	48.3	av. 49.7
Material above 10 mesh	36	29	20	33	50	35	av. 34%

Percentage analysis of material ret. No. 10 sieve:

Ret. $1\frac{1}{2}$ ", screen						
Passing $1\frac{1}{2}$ ", ret. $1"$	13				13	
Passing $1"$, ret. $\frac{3}{4}"$	13	18	15	3	10	11
Passing $\frac{3}{4}"$, ret. $\frac{1}{2}"$	23	23	15	15	25	19
Passing $\frac{1}{2}"$, ret. $\frac{1}{4}"$	39	37	52	39	38	39
Passing $\frac{1}{4}"$, screen	12	22	18	12	14	31
Above $\frac{1}{4}"$	29	23	16	29	43	24
						av. 28

It is estimated that Georgia has sufficient deposits along the state highways in the southwest section of the state to construct approximately 1000 miles of this type of base, 8 to 10 in. thick. This does not take into consideration county roads which will easily amount to 2000 miles additional.

COST OF BASE CONSTRUCTION IN GEORGIA

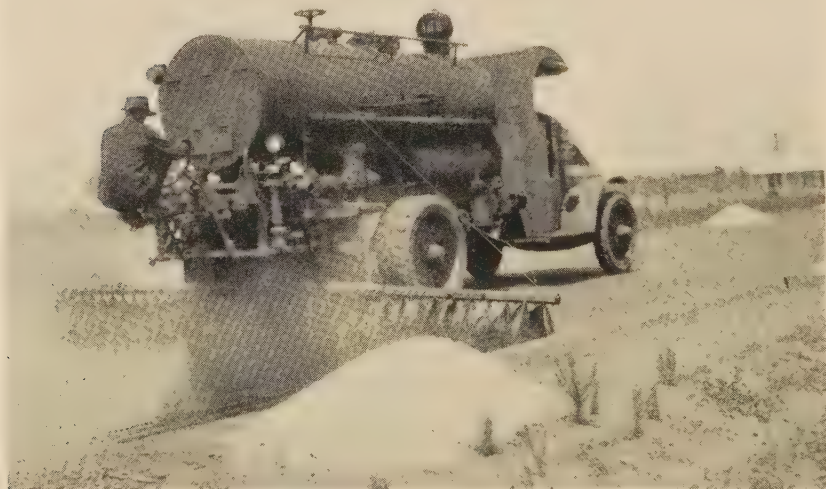
The State Highway Board of Georgia constructed quite a large mileage of chert, gravel topsoil and iron-oxide-silica bases at a cost varying from \$3,000 to \$10,000 per mile and allowed them to go unsurfaced for a number of years. Statistics proved that these roads depreciated from \$600 to \$1,500 per mile per year depending on the amount of traffic. When funds became available to surface these roads it was found that in most cases the base had to be renewed at generally 50 per cent of the original cost. The present ruling of the State Highway Board is to surface treat all remaining bases at the earliest possible time and to construct only this type of base with a view of surface treating it within six months in order to preserve the initial investment in the base.

After we have completed surface treating the present gravel bases and topsoil bases most of the surface treatments will be confined to clay-gravel, top soil, chert, and iron-oxide-silica soils, and then only within those sections where the materials can be obtained locally. We have surface treated all types and it is my opinion that the pebble soils or iron-oxide-silica bases give much better results than any other type of

base we have outside of lime rock. A base composed of 8 in. of iron oxide silica can be constructed for from \$3,000 to \$4,000 per mile and a surface treated top of the type we use for from \$2,000 to \$2,200 per mile, making a total investment of from \$5,000 to \$6,200 per mile. In my opinion there is no better investment a state can make than this type of construction on the secondary roads.

METHODS OF CONSTRUCTION

The most important step in the construction of surface treated roads is drainage. The composition of the materials is of such nature that water or moisture will act on the base and cause failure in the surface treatment. In case the base absorbs water by capillary attraction or



APPLYING 5/10 GALLON O. H. 1—MODIFIED ON TOP PRIME COAT, COLQUITT COUNTY, GEORGIA

otherwise in sufficient quantities the traffic will form an emulsion and gradually destroy the bonding qualities of the bituminous materials. Adequate side drainage should be provided, and, through the cuts, French drains constructed if necessary, so as to insure a dry base at all times.

In the construction of a sand-clay base for surface treating, great care must be exercised as previously stated in selecting the soils that have high stability. The quality of clay forming the binder is very important. Clays differ greatly in their texture and care should be taken not to use clays that are easily softened by water, such as gumbos, or clays that come in this category.

The general method of constructing a sand-clay base is to lay form-boards 12 in. in depth and deposit the natural sand-clay mixture, or, if an artificial mixture, in their correct proportions determined by laboratory

tests, to the top of the forms. Twelve inches of material will usually make 8 to 8½ in. of compacted material, depending on the shrinkage of the material used. The sand clay should be scarified and harrowed thoroughly to produce a uniform mixture and then machined constantly with a 12-ft. blade until the surface becomes compacted and smooth.

In Florida, due to the quality of clay available, they have found it advisable to add about 2 cu. yds. of pea gravel, spread over the surface for each hundred feet of base, and to allow the material to work into the surface under traffic, with constant machining by means of a one-man power grader. The pea gravel is added after the sand clay has practically taken its initial set. This method forms a crust or veneer surface that greatly increases the stability of the base. In Georgia we have such excellent sand clays coming under the high stability group that we seldom have to add metal to bring up the supporting value.

EXCELLENT SOIL DEPOSITS IN GEORGIA

Under the iron-oxide-silica group, or red pebble soils, of Georgia we have a natural material that excels all other materials coming under this group. Deposits of this material are found on top of ridges or hills. They run to a depth generally of 3 ft. from the top of the ground. The material is laid between forms generally 12 in. loose, which compacts to about 8½ in. After thoroughly mixing the material to get a uniform product the surface is machined generally with a 12-ft. blade until the true cross-section with crown obtained. One characteristic of this material is that it cements together very quickly. Usually a couple of good rains are sufficient for a thorough bond. This is not true of



APPLYING 50 LBS. OF ONE-INCH TO ONE-QUARTER-INCH SLAG ON THE SEAL, COLQUITT COUNTY, GEORGIA

sand-clay or gravel bases, which generally take a month or so to form their initial set.

During the early experiments in Florida the asphalt primes as first used did not prove very successful. Of these, material meeting the O. C. 2 Specification was most unsatisfactory. I quote Mr. R. L. Bannerman, division engineer of Florida, as follows regarding the use of asphalt primes in this early work:

"The principal trouble with asphalt for prime is that it requires too long for the prime to cure, which delays the application of the seal. Under heavy travel the prime tends to pick up before the same has cured sufficiently for sealing. Another trouble is the light oils in the asphalt prime tend to cut back the seal coat, which has caused us a great deal of trouble on the sections of road on which these materials were used."

Florida's experience, using asphaltic road oils as primes, covered a period about four years ago. They failed to attach themselves to the base, set up quickly and provide the hard mat needed to cause the seal coat to adhere to the same, and, for this reason, tar prime has since been used. Since the introduction of cut-back asphalts, however, satisfactory primes have been developed which have proven equal or superior to tars in many sections where they have been used.

APPLICATION OF BITUMINOUS MATERIAL

The next move was to find out the amount and viscosity of the bitumen to use. It was found that this depended on the density of the base and the character of clay used as a binder. The lime rock bases absorb from 2/10 to 25/100 per sq. yd. of a 8-13 viscosity bitumen. The clay-gravel bases will take 3/10 to 35/100 of a 13-18 viscosity bitumen. Sand-clay bases will take about the same amount of a 13-18 or 18-25 viscosity depending on the porosity of the material. The iron-oxide-silica soils take 4/10 of a 18-25 viscosity bitumen, and the penetration in this material will average $\frac{3}{4}$ of an inch. The engineer, therefore, must be familiar with the soils he is treating in order to determine the amount per sq. yd. and the viscosity of bitumen to use. This can be obtained only by experience.

The prime should be allowed to penetrate from twenty-four to forty-eight hours, depending on the temperature, and longer if good detours are available before turning traffic onto the surface. Only a small amount of cover or blotter material should be added as it will absorb the bitumen, thus forming a mat with no adherence to the base. Moisture then will form between the base and cover, causing a cleavage and cracking of the surface. Traffic should be allowed to use the prime base for at least two weeks to thirty days (depending on climatic conditions) in order to iron out any weak or soft spots before applying the seal coat. In case weak spots develop they should be cut out, reprimed and brought to a true plane with the surface by means of an asphaltic cold patch or other suitable material. During a two weeks' period between April and October in Georgia the prime generally will cure if the weather is favorable and will form a tough impervious surface.

The prime having thoroughly cured, the base should be swept clean of any foreign matter before applying the seal. The seal, consisting of an



COMPLETED SURFACE ON SAND-CLAY ROAD, COLQUITT COUNTY, GEORGIA

asphalt of 180-200 penetration, is then applied hot at the rate of 4/10 to 5/10 gal. per sq. yd. On lime rock bases 4/10 gal. per sq. yd. have been used in Georgia, while Florida has increased the application to 5/10 gal. per sq. yd. On clay treated bases 5/10 gal. per sq. yd. has been adopted by both states. I believe the quality of work obtained with the larger amount of asphalt will justify the increase. The temperature at which the asphalt is applied usually ranges from 300° F. to 325° F.

SPREADING THE COVER MATERIAL

The cover material, consisting of stone or slag, should be spread immediately after the application and while the asphalt is still hot. The cover material should be thoroughly rolled immediately with a roller weighing not less than seven tons. A ten-ton, three-wheel roller has been used with excellent results but the usual practice is to use a seven or eight-ton tandem. The drift to the edges should be kept swept back uniformly over the surface until the asphalt has taken up the maximum amount of cover material. During the first surface treatments in Florida they used O.H.-1 for the seal coat. This material did not prove entirely satisfactory so they adopted what is known as O.H.-1 modified, having the following specifications:

The asphalt shall not foam when heated to 248° F.

Specific gravity at 77° F. not less than 1000.

Flash point not less than 400° F.

Melting point (ring and ball) not less than 90° F.

Penetration at 77° F. 100 grams 5 sec. 180-230.

Loss at 325° F. 5 hrs. not over 1.50 per cent.

Penetration of residue not less than 150.

Total bitumen soluble in CS₂ not less than 99.5 per cent.

This material has also been adopted by Georgia with excellent results. Opinions differ as to the size and kind of cover material, but the following has been generally adopted by both Georgia and Florida. Slag gives better results than stone and a greater percentage of the cover material is composed of this type. It is more cubical in form and assures an interlocking of the aggregate and a mechanical bond under the roller that we do not obtain with stone. It does not dust or fracture as easily under traffic as the Georgia granites and is free of the flat or elongated particles so detrimental to bituminous surfaces. On account of its cubical shape and porous and angular nature it imbeds itself in the bituminous binder and forms a greater adhesion to the base. The cubical shape produces a non-skid surface and does not have the tendency to iron out under traffic as does stone. An inspection of the surface treated roads in Georgia and Florida will convince any one that a slag cover material is the equal if not superior to any other type of cover.

NATURE OF EARLY COVER MATERIAL

On the early surface treatments a cover material of $\frac{5}{8}$ to 10 mesh was used. This soon ironed out and became very sleek and dangerous to traffic in wet weather. This size was soon abandoned for a $\frac{3}{4}$ in. to $\frac{1}{4}$ in. which gave excellent results when four-tenths gallon of asphalt was used. Florida has roads with this sized cover material that are seven years old and still giving excellent service.

Both Georgia and Florida have adopted a cover material, 1 in. to $\frac{1}{4}$ in. in size, which appears from many angles to be superior to the smaller sizes. It does not have such a tendency to iron smooth and become



SAND-CLAY SURFACE READY FOR TREATING, WORTH COUNTY, GEORGIA

slippery in wet weather. It forms a non-skid surface and at a later date will more successfully take a retreatment. The amount of cover material may vary slightly, but it usually ranges around 10 lbs. for each tenth gallon of bituminous material. In other words we generally use fifty pounds for five-tenths gallon of asphalt which is our standard surface treatment.

DOUBLE TREATMENT IS TRIED

This year we tried in Georgia what may be termed a double treatment on a two-and-a-half-mile section next to Moultrie, Ga. After the first treatment had been subjected to traffic for three months, a second application of 3/10 gal. per sq. yd. of cut-back asphalt was used, having the following specifications:

	Min.	Max.
(1) Specific gravity, at 60 deg. F.....	0.980	1.01
(2) Engler specific viscosity, first 50 cc at 212 deg. F.	25	50
(3) Asphalt contents, at 100 penetration.....	85.0%	..
(4) Ductility of residue, at 77 deg. F.....	100 Cms.	..
(5) Evaporation loss, 20 grs. 5 hrs. at 212 deg. F.	10.0%	13.0%
(6) Penetration of residue, at 77 deg. F.....	..	200
(7) Evaporation loss, 50 grs. 5 hrs. at 325 deg. F.	12.0%	15.0%
(8) Penetration of residue, at 77 deg. F.....	..	125
(9) Bitumen soluble in CS2	99.5%	...
(10) Per cent of total bitumen insoluble in 86 deg. naphtha	20.0%	...

This treatment was covered with 25 lbs. of $\frac{5}{8}$ to 10 mesh slag. The surface was immediately rolled as well as swept with a seven-ton tandem roller, and the drift of cover material kept swept over the surface until the asphalt was cured and had taken up the maximum amount of cover material. This retreatment formed a tough, smooth, durable and impervious surface. The type of cut-back asphalt used did not have sufficient solvent to cut back the first application, but a sufficient amount to form a perfect bond with the surface. The curing period for this grade of cut-back asphalt is not over five days and leaves a surface that will not bleed or iron out, thereby causing a slippery condition in wet weather. The merits of this double seal cannot be proven at this time, but I am sure is worth the investment, provided funds are available. It will increase the cost approximately ten cents per sq. yd.

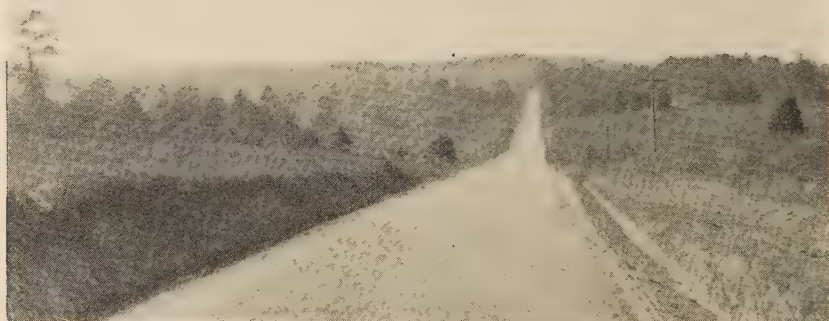
ROADS SUBJECT TO CONSIDERABLE TRAFFIC

Too much credit cannot be given Mr. J. L. Cresap, former state highway engineer of Florida, and Mr. R. L. Bannerman, division engineer, for developing and bringing the treatment of sand-clay roads up to the standard that is found in Florida and Georgia today.

Quoting Mr. Cresap, he says, "we have in Florida treatments on sand clay as much as two years and nine months old still giving good service under traffic as high as 1500 cars per day, and we believe, with proper

care in selecting materials and constructing the work properly, that sand-clay roads can be built and surface treated with the assurance that they will carry traffic up to 2500 cars per day, with a maintenance cost equal to that of other types of pavements."

Mr. Bannerman, who, possibly, has had more experience than any other person in this section in the maintenance of sand-clay treated roads believes that if the road is properly constructed the maintenance will be nominal and that retreatments will be needed only every four to five years at an approximate retreatment cost of ten cents per sq. yd.



COMPLETED SURFACE ON CHERT BASE, PICKENS COUNTY, GEORGIA: 33/100 OF A GALLON OF PRIME, 5/10 GALLON ASPHALT AND 50 LBS. OF ONE-INCH TO ONE-QUARTER-INCH SLAG COVER USED

The low cost road, or one that is dealt with here, is capable of carrying medium heavy traffic at a minimum maintenance cost and can be termed one of stage construction. At any time it can be changed into a high-type pavement, by constructing a black top, such as Amiesite, Macasphalt, or any of the other cold-mix asphaltic types, without stopping traffic. It is also an excellent base for laying the hot-mix types, such as binder and sheet, asphaltic concrete or any of the other hot-mix types, with very little or no base preparation except the construction of a curb for holding the materials.

This type of road is in its infancy and in Georgia the mileage of bases suitable for this type of construction will be worth, in a few years, several million dollars annually. In addition to the elimination of the dust hazard, this surface treatment will save hundreds of thousands of dollars annually by retaining the initial investments in the chert, clay gravel, red pebble, top soil and sand-clay bases.

CHAIRMAN WEDEKING: I want to express the appreciation of the people of Indiana for the compliment that is paid to Indiana when you selected the next number on this program. You have made it possible for us here in Indiana to carry out an old tradition in this state. Many years ago, when people went visiting on Sunday, they were provided with a great feast at noon time, and then along in the afternoon, when the visitors began to get ready to go home, the good housewife got a box or a basket and put into it some of the choicest bits of food left over from the bounteous feast at noon, and placed them in the carriage for the visitors to take back to the folks at home. You have made it possible for us to carry out that tradition here today. You are just about to get one of the choicest bits of this convention for you to take back home to the folks so that they can enjoy a part of the feast that has been provided here for you. I have more than the ordinary pleasure in presenting to you the next speaker, our own Mr. Hinkle, who is the superintendent of maintenance of the Indiana State Highway Department and who heads a force of loyal men who work under him and with him and who make of our highways the smooth roads on which you traveled to get here. Gentlemen, Mr. Hinkle!

Retread Construction in Indiana

By A. H. Hinkle, Indianapolis, Ind.

Superintendent of Maintenance, Indiana State Highway Commission

The program today is devoted to the consideration of "Low Cost Roads." Your program committee is to be commended for giving this subject the time and attention it deserves for the study and discussion of "Low Cost Roads" is quite appropriate. We who are in the business of road maintenance and construction sometimes become lost. We allow the turmoil and clamor to cloud the real objectives for which we are striving. We lose the true perspective of the situation and wander in the wilderness. We just follow the crowd.

Even to one standing on the "side lines" it should be evident that many types of road surfaces must enter into an economically developed highway system in order that "misfits" may not occur somewhere along the line between the lightest traveled local roads and heaviest traveled trunk highways. There is no more logic in arguing that we must build always the same kind of road than to say we must build always the same kind of house or wear the same priced suit. If we tried always to enforce upon society the same kind of house or the same kind of suit there would be a rebellion.

The average citizen is not well versed in road building. He does not understand the wear and tear of traffic on the surface of a road or realize its extent. The length of time required to observe the merits of many road surfaces in order to learn their relative economic value denies him the full perspective so necessary in making a study of the merits of each road surface. The study is complicated and tedious and is left to others

FIG. 3041



APPLYING "ROAD OIL A" TO GRAVEL ROAD TO BE USED AS BASE FOR RETREAD TOP.
INDIANA STATE HIGHWAY DEPARTMENT

to work out. Furthermore, the pocketbook is generally tapped in a more indirect way when building and maintaining highways than where one buys a suit or builds a house for himself, and for this reason the average citizen frequently gives little concern to this subject.

DUSTY ROADS OBJECTIONABLE

The greater speed of vehicles, together with the increased use of balloon tires, has made the dusty type of road surface objectionable, and out of place wherever the traffic is more than a few hundred vehicles per day or where the roadside is occupied by homes. Relief from the dust may be accomplished by the use of calcium chloride, oil, one of the types of cheaper bituminous tops such as the type described below, or one of the higher priced pavements.

During the past year the Indiana State Highway Commission resurfaced about 90 miles of old roads with "bituminous retread top." I know of no road surface that fits into the gap between the traffic bound surface and higher priced pavement any better than the surface we term the "bituminous retread top." This surface can be constructed very smooth. It is dustless and easily maintained, the maintenance costs not being high when the old road to be reclaimed has sufficient width and strength.

The bituminous retread top, with which this paper is primarily concerned, as we have been building it, consists of a mixture of bituminous material and crushed stone, slag or gravel, made by several applications

of the bituminous material to a layer of the aggregate spread on the old road. The mixture is kept smooth and uniform, by the use of a grader or planer, until the bituminous material hardens sufficiently to cause the aggregate to compact under a roller. The aggregate is rolled after the applications when the bituminous material is in the proper stage of curing. The surface voids that cannot be closed by rolling are filled with covering material ($\frac{3}{4}$ in. aggregate), *just preceding the third application of bituminous material.*

I shall comment on some of the salient features of this type of surface, leaving the specifications to be consulted for full details of the construction.

PREPARING THE OLD ROAD FOR USE AS A BASE

This bituminous retread top has been built on old brick and other types of pavements that have become objectionable because of roughness and disintegration. The holes and depressions in the old pavement first were properly patched. Generally it has been built on an old gravel or stone road. It may be placed on any kind of an old road that is sufficiently strong to carry the load to go over it. It may, however, be necessary to level and strengthen the old gravel or stone road. This may be done very economically by adding a liberal application of metal the preceding fall, winter, or early spring, which is compacted by traffic and "drag maintenance"; or by the use of a roller and stone screenings added to the coarse aggregate, as in waterbound macadam work.

FIG. 3125



SMOOTHING OIL TREATED ROAD IN INDIANA, BY USE OF A 32-FOOT DRAG. BY THIS PROCESS AN OLD ROAD WHICH IS QUITE ROUGH CAN BE MADE VERY SMOOTH, PREPARATORY TO PLACING THE RETREAD TOP

FIG. 3259



PATCHING "POT HOLES" DEVELOPED UNDER TRAFFIC IN OILED GRAVEL ROAD BY USE OF "ROAD OIL A" AND GRAVEL. THE OIL IS POURED INTO THE HOLE AND COVERED WITH LOOSE GRAVEL

Our experience indicates that the cheapest building up as well as leveling of the base, can be effected by treating the old road surface, coated with 1 in. to 3 in. of loose aggregate (sized for ordinary drag maintenance), with $\frac{1}{2}$ to $\frac{3}{4}$ gal. per sq. yd. of 40 to 70 viscosity road oil. The loose aggregate treated with the oil is spread and leveled over the surface with graders, planers and long base drags so as to make a perfectly smooth base on which to place the aggregate for the retread top. Super-elevations and depressions in the old surface can be built up by successive applications of loose gravel or stone and oil. The oil is of a sufficiently heavy grade to cement the loose aggregate and hold it in place after a few days' drying. Traffic may be permitted to use the road during this operation.

The use of road oil to solidify a layer of loose material on the old road surface is the most valuable feature put into practice in recent years in developing a low cost road that is better than a dragged type of surface. The oil-gravel mixture not only adds strength to the base, but forms a more or less impervious layer which sheds surface water and also breaks up the capillary attraction from the road base into the top course. It also greatly facilitates leveling the base and thus helps to obtain a smooth-riding, finished surface.

THE AGGREGATE AND THE SPREADING

Aggregate consisting of No. 2 ($1\frac{1}{2}$ in. to $2\frac{1}{2}$ in.) or No. 3 ($\frac{3}{4}$ in. to $1\frac{1}{2}$ in.) size (the coarser size is preferable) is spread upon the base

prepared as described above. The leveling of the aggregate is done by graders, drags, maintainers and harrows. The harrowing is necessary if the aggregate contains much fine material, as the harrowing operation will drop the fine material to the bottom and bring a more uniformly coarse aggregate to the surface, where it is most desirable in producing a uniform surface condition. It is always necessary to do a certain amount of hand finishing in trimming the edges and "spotting up" the low places; that is, filling depressions with uncoated aggregate before the application of the bituminous material, or with the bituminous coated aggregate after the application and when the rolling is in process. *However, the cheapness of this type of surface is due largely to the mixing, spreading and leveling operations being done mechanically, which reduces the hand labor, and hence the cost, to a minimum.*

FIG. 3169



DUMPING STONE FROM TRUCK FOR RETREAD TOP. THE LOW COST OF THIS TYPE IS DUE LARGELY TO THE MECHANICAL OPERATIONS USED IN SPREADING AND LEVELING THE AGGREGATE

APPLICATION OF BITUMINOUS MATERIAL

If the coarse aggregate is a very hard stone, it may be rolled one or more times before the first application of bituminous material. If a comparatively soft aggregate is used, *no rolling should be done* before the first application. There is little to be gained in rolling *gravel* before the first application. The aggregate used for covering material should consist of a hard material of about No. 4 ($\frac{3}{4}$ in.) size. It is applied to the surface and swept into the voids *just preceding the third application of the bituminous material.*

The bituminous material is applied to the aggregate in at least three

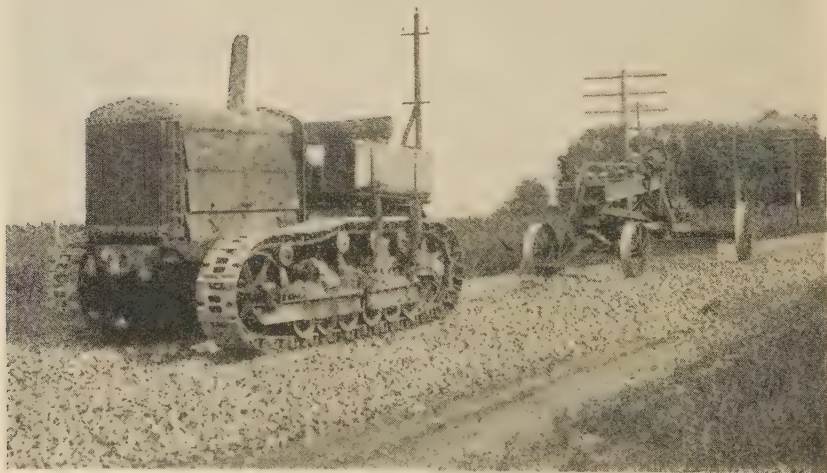
applications. More may be used. The total amount of bituminous material required, as well as the amounts used in the different applications, will vary with the depth of aggregate and hardness of the stone. As an example, on our average limestone the different applications of bitumen on 3½ in. of loose aggregate may be 0.4 gallon on the first, 0.3 gallon on second, and 0.3 gallon on the third coat, with perhaps a 0.2 gallon surface treatment applied before the following winter.

NATURE OF THE ASPHALTS USED

Various grades of bituminous materials have been used in this class of work with very satisfactory results. The most common material we have used is material meeting our specifications for Liquid Asphalt CB (a cut-back asphalt with specific viscosity 150 to 200 at 122° F.) and tar TM (specific viscosity 30 to 60 at 40° C.). If the work is done in cool weather, it is more desirable to use the Liquid Asphalt AC (vis. 50 to 100), which differs from the CB only in the greater amount of distillate it contains. The lighter bitumen makes the aggregate more susceptible to mixing and leveling with the grader or planer. However, in warm weather the heavier grade of asphalt will give quicker results at slightly less cost.

Asphalt OH—2 (penetration 175 to 250) has frequently been substituted for the liquid asphalts in the second application in order to reduce the cost. The OH—2 usually costs about 2 cents per gallon less than the liquid asphalts. Its use also permits rolling about one day earlier. Since it is desirable to drag the covering material, it is necessary to again use the liquid asphalts for the third application. It is

FIG. 3167



STONE DUMPED FROM TRUCK ON OLD ROAD BEING LEVELED BY USE OF CATERPILLAR TRACTOR AND GRADER. IN THE REAR, WORKMEN ARE OBSERVED TRIMMING THE EDGES AND "LEVELING UP"

FIG. 3272



HARROWING THE RETREAD AFTER APPLICATION OF THE ASPHALT. INDIANA STATE HIGHWAY DEPARTMENT

not always economical to use OH—2 because of the fractional cars required.

APPLYING THE COVERING MATERIAL

The covering is applied just preceding the third application of bituminous material. It may be applied direct from a truck and swept over the surface by hand. The brushing of the covering into the voids may be done with a brush attached to a Ford car or light truck. An old carpet or tarpaulin dragged behind the truck will aid in placing the covering properly. The purpose of the sweeping is to roll the covering stone around over the surface until it drops into the voids of the coarser aggregate and fills all depressions, thus producing as near a level surface as possible. After the third coat of bituminous material is applied, the surface is dragged with a light drag or maintainer, thus materially aiding in leveling the finished road. The size of covering stone may vary somewhat with the size of coarse aggregate, using a coarser material where the coarse aggregate leaves larger voids in the surface.

ROLLING BEFORE APPLYING COVER MATERIAL

After each application of bituminous material the surface is rolled with a ten-ton three-wheel roller. *In no case is covering material applied before the rolling.* By this means a more uniform and a smoother riding surface is produced than if covering material is applied between the application of bitumen and rolling. Water is applied to the roller wheels to prevent the bitumen from sticking to them. This rolling should be *spread out over a number of days while the bitumen is hardening.* The important time to secure the best results from the rolling is when the

bitumen is sufficiently stiff and "tacky" to prevent the stone from being "mushed" out of shape by the roller wheels, and, at the same time, not so hard as to be dry and brittle. As the bitumen stiffens and hardens the rolling should be speeded up. Too much rolling can hardly be done at the proper stage of curing. One rolling when the bitumen is in the proper stage of curing is worth several rollings when the bitumen is too soft or too hard. All bituminous mixtures respond most readily to the rolling operation when the bitumen is in the proper stage of curing. The best results frequently are not secured in this class of work because the rolling is not performed at this most desirable time. The proper time to do the major portion of the rolling is governed by the air temperature and the sunshine and the grade of bitumen used, as these three factors will control the rate of hardening of the bituminous material.

ALTERNATE METHODS OF MIXING

Two distinct methods of manipulation have been followed after the first application of bituminous material. The first method consists of harrowing and blading the coarse aggregate after the first application of bituminous material, so as thoroughly to coat all the stone before rolling. In the second method the harrowing and blading after the first application of bituminous material is omitted.

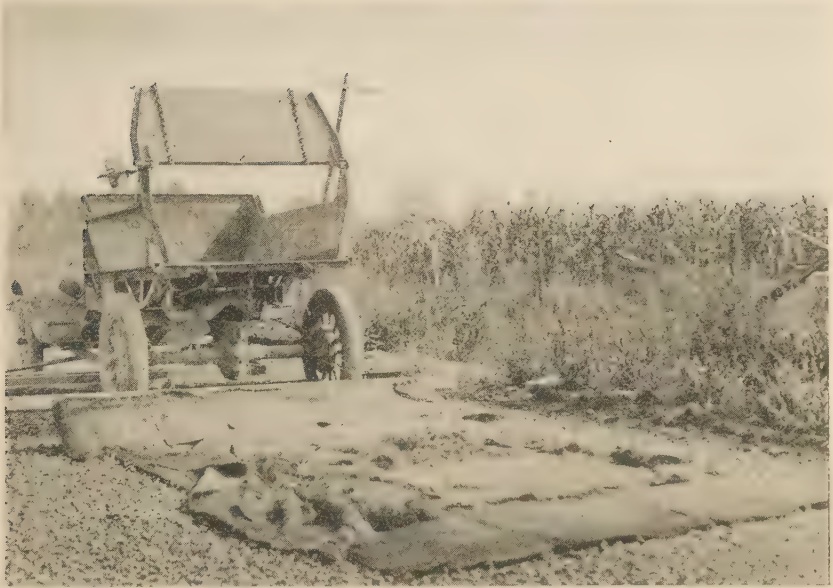
It is extremely desirable that the aggregate be thoroughly dry when the bituminous material is applied. The principal difference between many of the plant mixes and a mix made on the road as described above, is that in the plant mix the aggregate is heated until dry. If the aggregate is thoroughly dry from the warm, sunshiny days of summer, the

FIG. 3273



BLADING AFTER HARROWING TO SMOOTH THE SURFACE BEFORE ROLLING. INDIANA
HIGHWAY DEPARTMENT RETREAD WORK

FIG. 3281



SPREADING THE COVERING MATERIAL AND BRUSHING IT INTO THE VOIDS WITH A CARPET AND BRUSH ATTACHED TO A FORD TRUCK JUST PRECEDING THE THIRD APPLICATION OF BITUMEN

mix made on the road need differ little from the plant mix as far as the adhesion of the asphalt to the aggregate is concerned. The use of the cut-back asphalt also aids in the field mix duplicating the plant mix.

SOME EXPERIMENTATION NECESSARY

There are many pitfalls which one may encounter in doing this class of work. As with all bituminous mixtures, it is almost imperative that one practice or experiment in doing this work to some extent, or that he have the advice of a person who has had this experience, if he is to be assured of success. We have had foremen who did an excellent job the first time under the advice of a proper instructor, but upon the second attempt proved to be a complete failure because of their limited experience and the lack of guidance of a sufficiently experienced man. Outside of the proper levelling of the surface, perhaps the greatest precaution that should be taken is to avoid using too much bituminous material and to use the right amount and grade of covering stone in the finishing process. One should bear in mind that it is always possible to add another coat of bitumen if an insufficient amount has been applied, whereupon, if at any time too much is applied it is impossible to remove the excess. The building on the surface of a thick mat of fine aggregate rich in bitumen, should be avoided as this is liable to result in the "waving and rolling" of the surface in later years, which is so characteristic of many bituminous surfaces.

The road oil we applied this summer to the roads averaged five and three-quarter cents per gallon—three or four hundred dollars per mile.

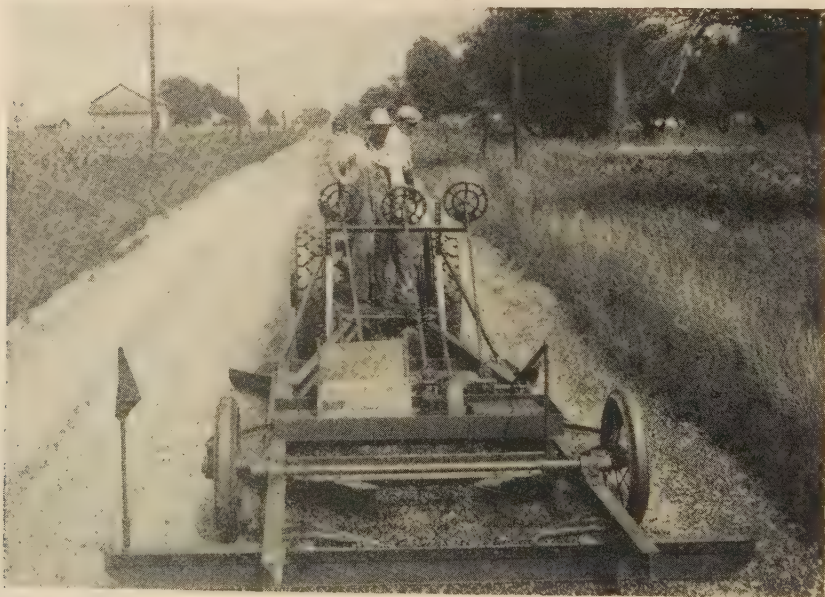
I tell the boys they'd better make the retread so lean that a certain amount of the spots will ravel, which spots can easily be patched rather than put on so much bituminous material as to cause waving or shoving. I have about fifteen or twenty slides. I have not the slides to illustrate all the operations, but most of them are commonplace. This is a view of the application of the road oil, which we call "Road Oil A," to the old surface. The loose gravel is scraped off to each side of the road with a long blade grader, the oil is applied with a distributor and that is followed immediately by a grader pulled by a tractor, scraping the loose gravel back over the oiled surface. One operation brings it back almost over the entire width that is oiled, and after that operation the surface is maintained for any length of time we desire or until we are ready to build the retread by the use of a long base drag.

TYPES OF GRADERS AND DRAGS

We use various kinds of graders and maintainers. This shows two of our standard three-blade wooden drags fastened together, making a drag thirty-two feet long. It is easy to see that a drag that is long and heavy, pulled by a caterpillar tractor, produces a perfectly level surface. So you will find no "bumps" in the surface. The oil coating on the gravel or stone is put on in quantity sufficient that, after curing a few days, it is tight enough to hold the gravel in place.

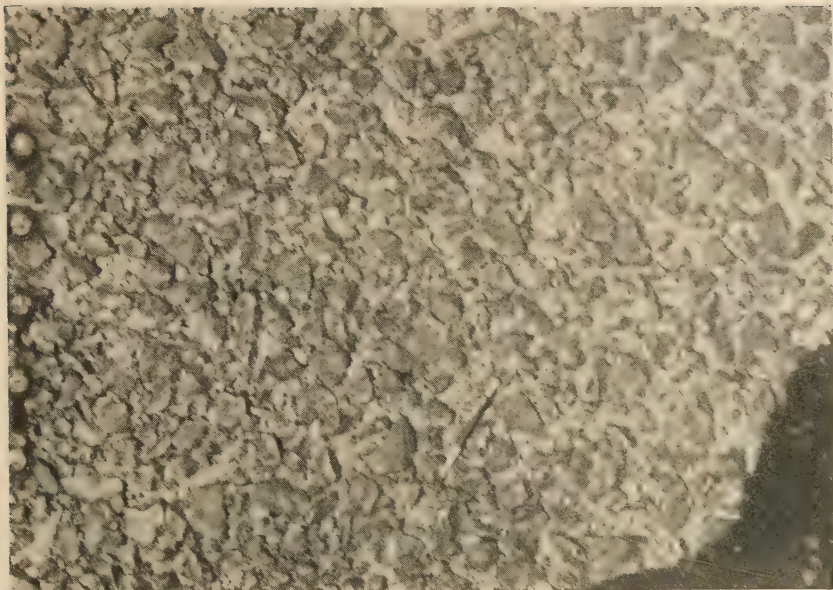
Sometimes a grader is placed between the tractor and the drag to scrape in from the edge some loose material that has not been secured in the first operation. This view shows the method of patching these

FIG. 3161



DRAWING COVERING MATERIAL AFTER THIRD COAT OF BITUMINOUS MATERIAL HAS BEEN APPLIED. THIS PROCESS ROLLS THE COATED STONES AROUND UNTIL THEY DROP INTO THE VOIDS AND FILL ANY LITTLE IRREGULARITIES IN THE SURFACE. AFTER THIS OPERATION THE SURFACE IS ROLLED THOROUGHLY

FIG. 2801



CLOSE-UP VIEW OF BITUMINOUS RETREAD TOP WHICH WILL REQUIRE ANOTHER TREATMENT BEFORE GOING INTO THE WINTER

oil-treated roads where the retread top has not been put on for several months, but allowed to be used by traffic as an ordinary oiled road and which has developed "pot" holes under traffic. The process is very cheap. The oil, unheated in this case, is poured into the hole and a shovel of gravel is thrown on the oil. We find that this method of maintaining the oil-treated gravel surface where we did not put the retread top on, proved very inexpensive.

PLACING THE RETREAD STONE ON SURFACE

After the base is properly developed, the retread stone is placed on the surface by distributing it over the surface from the truck. Frequently, in order to allow the road to be used by traffic, the aggregate is stored in piles along the side of the road and later spread over the surface by a grader. This shows the finishing or levelling process with the grader pulled by the tractor. You will see some six or seven workmen in the distance who are doing the final levelling and are lining up the edges. A certain amount of stone rolls off the edge, which is lost unless scraped back. This is the operation of harrowing after the first application of bituminous material, in order to mix the cut-back asphalt with the aggregate. The harrowing also helps *level* the surface. A certain amount of additional levelling, however, has to be done, because the harrow does leave some ridges.

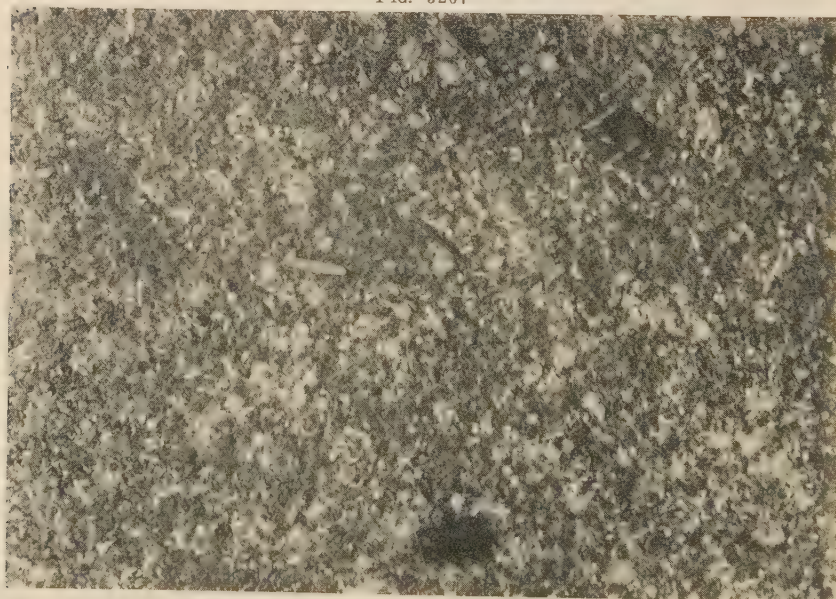
This shows a grader being pulled over the surface to aid further in levelling it just before the rolling is done. I have skipped several operations from the previous view to this one. The rolling is done on the

surface, and then the second application of bituminous material is made and the surface again rolled. The covering material is applied just before the third application of the bituminous material. In this method the work is all done at a minimum cost. Instead of wasting part of the covering material in piles alongside the road and putting it on by hand, the covering is put on direct from the truck. Here is a method of spreading the covering. A brush under the truck rolls the covering stone around, and as much of it as can drops in the voids. The voids are thus filled with the loose covering material. After this operation the third coat of bituminous material is applied direct to the covering stone, and the surface is planed with this planer, which rolls the bituminous coated stones around over the surface, making a bituminous concrete and pushing it down into the voids of the coarser aggregate.

HOW DRAGGING FILLS THE VOIDS

It is surprising to note how much of the covering stone disappears in this operation. Some of our men thought the dragging of the covering stone was not necessary, but after they dragged it four or five minutes and found much of the covering stone disappeared in the voids of the surface, they realized the importance of the operation. The surface is then again rolled, and we find the surface quite open, as shown in this view. The size of the stone used there is shown by comparing it with the fountain pen. The surface frequently is left in that condition until near winter time, in order to avoid getting too much bituminous material in places, and just before going into the winter a seal coat of two-tenths to a quarter of a gallon of cut-back asphalt is applied with some $\frac{1}{2}$ in. covering to seal the surface.

FIG. 3267



CLOSE-UP VIEW OF FINISHED RETREAD TOP SHOWING THE VOIDS IN THE COARSER AGGREGATE FILLED WITH THE BITUMINOUS-COATED COVERING STONE

FIG. 2850

FINISHED RETREAD TOP THROUGH THE BEAUTIFUL, HILLY, LAKE DISTRICT OF
NORTHEASTERN INDIANA

IMPORTANCE OF THE EDGES

This is a finished surface with the voids pretty well filled, so that you can just notice the large stones peeping through but no open voids.

This shows a place where the edge went down, due to bad foundations. Sometimes our roads were only ten or twelve feet wide in the early days, and in widening, the tops extended out beyond the base, which failed under heavy hauling and was patched next spring, the same grade of cut-back asphalt being used.

SURFACE PUT TO THE TEST

This shows the surface being swept after patching, preparatory to another surface treatment. That little sweeper is the most economical means of sweeping the surface of which I know. I forget what the sweeper cost, but it was very reasonable and its operation is also very low.

This shows a farmer testing one of the retread roads. Before the third coat was applied he wanted to move a tractor. We had the surface only three-fourths done, but it was such a serious thing to him to go around that we let him go, and if you went there today you would not find any indication of the holes his tractor tore in it.

This shows State Road No. 27 in the beautiful hill-and-lake district of northeastern Indiana. Indiana has some beautiful grounds and also some good fishing.

This is a view of State Road No. 12, the Dunes Highway, in the north-west corner of the state, where there is a four-foot retread surface built along each side of a 20-foot concrete pavement. The traffic is so heavy there that it was impossible for a traveler to change his tire on the pavement, since the shoulders were sand, and if he drove off the road he usually stayed there. We build a four-foot shoulder of retread with a slag base. It makes the road much safer and provides a place where a man can turn out to repair a tire or turn out in case of emergency.

FIG. 3213



LIGHT, BITUMINOUS RETREAD, CONSTRUCTED TO A WIDTH OF FOUR FEET ON EITHER SIDE OF THE DUNES HIGHWAY IN NORTHERN INDIANA TO MAKE THIS ROAD SAFER FOR THE HEAVY, HIGH-SPEED TRAFFIC WHICH IT CARRIES AND WHICH FREQUENTLY TURNED OUT AND PASSED OVER THE SHOULDER THAT FORMERLY WAS OF SAND, CAUSING SERIOUS TROUBLE

CHAIRMAN WEDEKING: If Mr. Hinkle had submitted his paper to me before he read it, I would have had him change the statement in which he said that the public was not well versed in road building. If he sat in my office and heard the public come to me and tell me how to build roads, he would know that they are well versed in that subject. They may not always agree, but they are well versed. (Applause and laughter.) We have a discussion of this subject also this afternoon by a man who is a neighbor of ours and with whom we have the friendliest relations. We let his people drive on our roads and he lets our people drive on his roads. He was patient enough to sit here and listen to all of these discussions in order to hear Mr. Hinkle's discussion. Now we are going to ask him to present his discussion. Then the papers will be thrown open to general discussion by all those who care to participate. I have great pleasure in introducing Mr. J. S. Watkins, state highway engineer of the Kentucky State Highway Department.

Bituminous Surfacing on Low-Type Gravel or Traffic-Bound Roads in Kentucky

By J. S. Watkins, Frankfort, Ky.

State Highway Engineer, Kentucky State Highway Department



J. S. WATKINS, STATE HIGHWAY
ENGINEER OF KENTUCKY

The use of asphalt for the surface treatment of roads began approximately twenty-five years ago. In Kentucky the surface treatment of macadam roads began twelve years ago. At the time that the automobile came into use in Kentucky—approximately twenty years ago—many of the counties located in the "blue grass section" of the state had a network of good macadam roads. Many of these roads were laid out and built almost one hundred years ago, when Kentucky had its first state highway department. The counties had been able to maintain these roads in good condition for the horse and buggy traffic of the former days; but after the automobile and truck came into general usage these roads soon commenced to deteriorate and go to pieces, so that it was found that the old method of filling up the holes and ruts with loose, napped

and crushed stone would no longer maintain the roads in good condition, because all such loose stone was whipped out to the roadside by the fast-moving vehicles.

OLD MACADAM ROADS PRESERVED

After the first few sections of main highways were surface treated, the old method of maintenance soon began to disappear, and, with good business management, progressive improvement and periodic surface treatment, many of these counties have preserved their entire mileage of macadam roads that were fast deteriorating and going to pieces. Today they have a network of several hundred miles of wonderful county highways.

After the first surface treatment work was done in 1917 by our state highway department, it soon became apparent that every mile of macadam road could best be preserved and maintained after it is surface treated, so our department has under maintenance today a total of 1072 miles of surface treated macadam roads which were constructed as the water-bound type.

THIRTY-FIVE COUNTIES WERE ISOLATED

After spending the greater portion of our revenues for a period of seven years in linking up the largest centers of population in the state with through highways of the more expensive type, we found, on the

first of January, 1928, that thirty-five counties, out of the one hundred and twenty in Kentucky, were isolated and without means of highway communication during the winter. These thirty-five counties comprise one-third of the area of our state. At that point our department decided on the building of the greatest mileage possible of the low-type surface to serve these isolated sections and get the people out of the mud. Many of these counties had less than 100 automobiles registered. Three or four had even less than 15, while some of the counties in the coal fields had as many as 2000. The policy adopted by our department was to build into these isolated sections a type of surfacing that can be improved and developed into a high-type road as the section served develops and traffic increases and demands it.

SALVAGING A GOOD INVESTMENT

On January 1, 1928, we had under maintenance a total of 3259 miles, of which 2695 were surfaced. On January 1, 1930, at the present rate of progress on our construction, we will have under maintenance a total of 4800 miles, of which 2250 miles will be the so-called low type, consisting of untreated traffic bound macadam and gravel surfacing. The traffic is increasing very rapidly on these roads, and the loss of material, as well as the dust nuisance, is becoming a serious problem that must be solved on quite a large percentage of the mileage already constructed.

It is no longer a question with our department as to whether the traffic-bound and gravel road types are a good investment, and that our policy in building these types is wise, for during the past two years we have served a total population of approximately 600,000 people, heretofore isolated and without surfaced highway connections. And this policy has met with general approval. Neither is there any further question as to the treatment of these low-type roads, in so far as we are concerned, for during the past three years we have converted five hundred miles of traffic-bound and gravel roads to what is generally known as high-type road with a bituminous treatment, which is commonly known as "retread," or designated by our department as "bituminous road-mixed treatment." It is not a question now, after our experience, as to whether this treatment is satisfactory, because the service record on these five hundred miles answers that question. It is now only a question of how much money can be budgeted each season to convert the low-type gravel and traffic-bound roads into "black-top high type or semi-high type pavements."

REPLACEMENTS WITH CRUSHED STONE

We are convinced from our past experience that, before a bituminous treatment is placed on bank or river gravel surfacing, a much more satisfactory treatment is secured where necessary replacement of floater material is made from one or more years prior to treatment, using crushed limestone of suitable size. We believe that a compacted surface of limestone from one inch to one and one-half inches adds greatly to the adaptability of the road for receiving the treatment, as well as providing a better waterproof surface and increasing the bearing value. So, in the discussion of the subject assigned to me, which has been so thor-

oughly covered by Mr. Hinkle, I can best discuss it on the basis of the experience in my state.

DESCRIPTION OF TREATMENT APPLIED

In preparing a section of road for this treatment extreme care is taken completely to clean the surface of all foreign matter by the use of hand and power brooms. In some cases picks and shovels are resorted to in an effort to secure as much cohesion as possible between the treatment being applied and the existing surface. Following the cleaning operation, a prime application of the bituminous material adopted for the treatment is applied at the rate of approximately one-fourth of a gallon per square yard. Immediately following this prime application, limestone covering material, meeting the following screen analysis, is applied, generally at the rate of one hundred pounds per square yard:

SCREEN ANALYSIS

Per cent of wear not more than.....	6.5%
Passing $1\frac{3}{4}$ in. round laboratory screen.....	100%
Passing $1\frac{1}{2}$ in. round laboratory screen.....	90-100%
Passing 1 in. round laboratory screen.....	30- 70%
Passing $\frac{1}{4}$ in. round laboratory screen.....	0- 5%

In some cases where the treatment is applied to old bituminous surfaces of various kinds, the rate of the application of the covering material is reduced to seventy or eighty pounds per square yard.

APPLICATION OF BITUMINOUS MATERIAL

Immediately following the placing of covering material, an application of approximately three-fifths of a gallon of bituminous material is applied, after which the stone is turned on the road by the use of road graders or maintainers of the standard type. After the material in place has been thoroughly mixed, it is again spread over the road surface and additional bituminous material is applied in sufficient quantity to complete as nearly as possible the uniform coating of every stone particle with bituminous material.

CUT-BACKS USED SUCCESSFULLY

Generally for each ten pounds of covering material one-tenth of a gallon of bituminous material is used. Grading is continued up to the time that the mixed material is making its initial set, at which time the entire surface is thoroughly rolled with ten-ton, three-wheel rollers. In some instances we have found a seal application of limestone chips ($\frac{3}{4}$ in. to $\frac{1}{4}$ in. size) and approximately one-fifth of a gallon of bituminous material necessary, principally on sections furnished by quarries which have a ready demand for limestone chips to be used in surface treatment.

Several specifications have been tried out in our state for the use of asphalt cut-back material. We believe at this time that the following material has proven to be the most satisfactory.



RETREAD SURFACE ON OLD MACADAM. FRANKFORT-LEXINGTON ROAD IN WOODFORD COUNTY, KENTUCKY

ASPHALT CUT-BACK

Specific gravity 25° C. not less than.....	93
*Specific viscosity at 40° C., 50cc.....	125-175
Loss at 163° C., 5 hrs. 20g.....	15-25%
Penetration residue at 25° C.....	30-90
Specific gravity of distillate 25° C. to 170° C.....	70-80
Ductility of residue after distillation, not less than.....	100 Cm.
Total bitumen (soluble CS ₂) not less than.....	99.5%
Per cent of bitumen (insoluble in naphtha) 86° B., not less than	15%

*Note: The department reserves the right to specify a definite specific viscosity for the above material.

COST DATA ON KENTUCKY WORK

In drafting a revised general specification for our 1930 construction work we have decided to specify two distinct sizes of material in the course aggregate of the treatment; the first size to range from $1\frac{3}{4}$ in. to 1 in., and to be sealed with chips ranging from 1 in. to $\frac{1}{4}$ in. We are quite confident that a much more uniform surface will be secured and that the danger of segregation in the covering material will be eliminated.

On 222 miles of this treatment placed during the season of 1928 our records indicate an average cost of \$2,600 per mile, or 26 $\frac{1}{2}$ cents per square yard. We find that so far we have experienced very few failures, practically all of which can be charged, not against the method of application of the treatment, but against faulty drainage or soil conditions

in the subgrade. The maintenance costs, as shown by accurate distribution of cost on all maintenance work, compare very favorably with costs of surface treated macadam and bituminous penetration macadam surfaces.

KENTUCKY'S LOW COST ROAD PROGRAM

I feel perfectly safe in saying to this group of men interested in the production of asphaltic materials that, during the next construction season, we will place at least 400 miles of the low cost surface, described above, in Kentucky. Many of our main trunk-line highways are as yet being maintained as gravel or loose stone roads, and public sentiment is rapidly crystallizing along these routes in favor of many miles of this low cost type of surface in preference to the few miles of high-type pavement which may be built with the available funds.

In my judgment, the one grave danger which may arise out of treatments of this kind is that, in their desire quickly to accommodate the public, the counties, communities, and state departments will allow themselves to be persuaded into placing a road-mixed treatment before a base of proved merit has been established.

VALUE OF LOW COST ROADS

Of course, there is always the question as to whether it is not more economical to apply a second treatment in case the first does not sustain the traffic satisfactorily when base failures occur. We have experimented in a very small way recently with a surface-mixed penetration pavement using stone ranging in size from $2\frac{3}{4}$ in. to $\frac{1}{2}$ in., and using



RETREAD ON OLD MACADAM. ROAD BETWEEN FRANKFORT AND LEXINGTON, KENTUCKY. STATE HIGHWAY DEPARTMENT OF KENTUCKY



RETREAD WORK IN KENTUCKY. ROUTE NO. 60 BETWEEN LOUISVILLE AND FRANKFORT ON "JUNIPER HILL." OLD MACADAM ROAD UTILIZED

similar bituminous materials and methods to those outlined above, and we believe that a more satisfactory surface can be obtained from the present method of placing standard bituminous direct-type penetration pavements.

OTHER STATES HAVE SIMILAR PROBLEMS

As I see the situation, many states are confronted with problems similar to those which we are facing in Kentucky. With standard grade and drain construction costing at the rate of approximately \$12,000 per mile; with a total revenue of approximately \$15,000,000 a year, out of which probably a little more than \$9,000,000 can be allotted to construction, it is very apparent that the public is demanding roads faster than a highway department with such revenues can construct them—if such construction consists only of high-type pavement costing \$30,000 per mile, thereby making the total cost of the road, including grading and drainage, \$42,000 per mile.

After all, a road should be designed to take care of the traffic needs, and the policy that our department has followed in the past two years, in building high-type pavement on initial construction on the main or trunk-line routes and the building of the progressive or stage construction type into the undeveloped sections, has been fully justified by the results we have obtained and the service rendered to the people.

CHAIRMAN WEDEKING: I am sure after hearing this discussion by the gentleman from Kentucky, you will all be glad to heed a suggestion which I am about to make, and that is that at the first opportunity you pay a visit to the capital of the State of Kentucky and let some of the folks

down there pilot you over some of their roads. They have delightful drives and wonderful estates, stone fences, parkways and things of that kind, and here and there is a halfway house, and after you have stopped at some of these halfway houses, you will readily see that the Kentucky people have an easier way of pleasing the folks because the roads don't seem as rough as they are. (Laughter). Now gentlemen, I am coming to one of the most embarrassing parts of my share in this convention. Twenty-three different men who are attending this conference have asked me to call them by name to discuss these papers, and I cannot call on twenty-three men in the time that is left, so I am not going to call on any one of these twenty-three, but I am going to ask Mr. B. E. Gray, from West Virginia, to substitute for all twenty-three of them, and I am advised that he can do it. Mr. Gray!

Methods Required to Produce Enduring Smoothness in Bituminous Macadam Surfaces

By B. E. Gray, Keyser, W. Va.

Division Engineer, State Road Commission of West Virginia

I feel that we are all greatly indebted to Mr. Hinkle for a very excellent presentation, and certainly the results which he has obtained in his state are evidence not only of his thorough knowledge, but further, and just as important, they indicate a determination to carry precept into practice. Anyone who has traveled widely over the United States must admit that there is a wide variation in the quality of bituminous pavements, and that some of them are nothing short of disgraceful. Much of the criticism directed against "black top" has been justified, not as a result of bad specifications or poor material, but because either of lack of intelligence or the necessary will to carry on the construction in a proper manner. I believe that it is well to be frank with ourselves in this matter, so that correction of the faults will come that much earlier. I have driven over many thousands of miles of bituminous roads during the past twenty years, and I have built a few of them myself, and the following brief discussion is based upon observations and experience thereby gained.

IMPROVEMENT BY STAGE CONSTRUCTION

All too frequently macadam roads have been built as if they were to be temporary surfaces,—a wrong attitude to begin with. Any improvement to a state highway should be with the idea that stage construction is possible, and as traffic increases, the surface may be strengthened and widened, utilizing all previous work. This means that even for low cost roads, careful attention should be given to alignment and grade, and with drainage structures properly placed to take care of future changes with minimum cost. There is no reason to slight work just because funds are limited. On the contrary, the best engineering talent should be employed to obtain maximum results from these limited expenditures.

As in every other phase of human endeavor, there is usually a reason for any particular set of conditions, and in the construction of macadam types, poor results come about largely because of too little insistence in the observance of fundamental principles, and the hope (if it may be so termed), that in some way a good surface would finally happen. It is all very well for a group of executives to get together and write a set of specifications for methods and materials. It is quite another to go back home and build an organization of engineers and inspectors to carry them into practice, especially with the "feast or famine" condition that exists in public work. And yet it is upon the inspector that success or failure largely depends. He must be sold on the need for doing work as planned, and imbued with a desire to obtain quality results,—never satisfied with anything less.

HISTORY OF EARLY MACADAM SURFACING

Early macadam roads were built by laying either crushed or knapped stone upon road beds which had been stabilized under horse-drawn traffic. The layer of stone was filled with screenings, and then water bound and



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rolled. Under iron-tired traffic there was gradual wear so that additional dust was continually being worked into the voids, and over a period of years these surfaces became very firm and fairly smooth. Any serious variations were repaired by adding fine stone and additional screenings, and for the slow moving traffic, no particular need was felt for extremely even surfaces.

With the advent of the automobile, however, such surfaces deteriorated very rapidly, due to tire suction and consequent loss of filler. The first experiments with surface treatment brought widely varying results, but in general they were satisfactory and adequate for motor vehicle speeds of not over 25 miles per hour. With the further growth of traffic, rapid extensions of roads were made. The old methods of construction were still followed, and on new road beds much settlement occurred, until, in many instances, macadam types obtained a bad name because of roughness. No particular requirement was made as to checking subgrade and base, it being generally thought that all irregularities could be taken out when the top course was placed. It is need-

less to add that experience soon showed that such conclusions were erroneous, and resulting from the experience gained over the intervening years, state highway specifications have been written, so that they now take into account the absolute necessity of giving as close attention to every step in the construction of a macadam surface as for the most costly pavement.

The West Virginia specifications of 1929 call for subgrade to be prepared in accordance with profile, grade and cross-section, with variations not to exceed $\frac{1}{4}$ in. in 10 ft. of length. Before placing any stone, the subgrade is to be thoroughly rolled, all weak or soft places to be stabilized with solid material, and the entire area to be checked prior to placing any stone. Specifications for the stone call for a product of uniform quality, proper grading and size. Extreme care is taken in placing the base course to see that uniform depth is obtained, and the surface is closely checked. Every care is then taken to see that the base course is *thoroughly* filled with stone screenings and dust in order that all voids shall be full and no movement in the base course possible. It is preferable that new base course shall be constructed one year, and top course laid the year following. There is a decided tendency to change the specifications and methods of construction so as to follow this plan.

BASE COURSE METHODS IN WEST VIRGINIA

Where the base course is laid one year and then opened to traffic through the following winter, the surface should be treated with asphalt in two applications, the first consisting of $\frac{1}{4}$ gal. asphalt primer coat, which is readily absorbed and requires no cover, and the second application of $\frac{1}{4}$ gal. cold liquid asphalt applied several weeks afterward, and covered with approximately 20 lb. of chips. In no case should base course be laid upon road beds graded the same year (unless absolutely necessary), as some settlement is bound to occur with resulting distortion of the surface.

While knapped stone base of fair quality has been laid, yet in order to obtain really smooth riding surfaces this type should be discouraged and crushed stone used instead. As a further step in obtaining smooth surfaces, this crushed stone base should be built up in layers, each not to exceed 4 in. compacted depth. Specifying such a maximum depth insures thorough filling, and consequent less likelihood to move under traffic. To obtain the results which will comply with these specifications throughout, requires most rigid inspection. The old methods of laying macadam pavement had become so well established that very few contractors appreciate this need for refinement, and, failing to see the value of checking so closely, constant supervision is required on the part of the inspector to see that proper results are obtained.

CARE IN CONSTRUCTION OF BASE COURSE

Somebody has said that "genius consists of an infinite capacity for taking pains," and certainly the construction of macadam pavements of extra smoothness depends entirely upon such attention. To insure high quality, several additional types of equipment have been devised, and used successfully during the past season. The old time straight-edge, of course, together with the template for obtaining proper cross-section, are used constantly on both subgrade, base course and top. After surface treatment of the base course, and prior to placing the top, an additional instrument has been tried, known as the "grade-rater." This is a wooden frame, approximately 10 ft. in length, with a small wheel at each end, and having in the center, a metal pointer which drags on the surface

of the pavement and indicates any variation (in fractions of an inch) on a scale at the top. The machine is operated with a pair of light plow handles and the scale is readily visible to the operator. The method is to push the machine longitudinally with the road, and whenever the scale indicator shows a variation beyond the specification tolerance, a chalk mark is made indicating the high or low area. The "grade-rater" is run down and back twice on either side of the center so as to cover every 4-ft. interval of width. All areas which vary from the true surface are patched before placing the top course. In making these patches, the greatest care should be taken to use a minimum amount of asphalt, in order that no change in texture may occur. It is *essential* that the base course conform exactly to the desired cross-section and profile, if the final surface is to remain smooth.

APPLICATION OF THE SEAL COAT

The same care is taken in placing top courses; first, to obtain a uniform material with the densest possible grading, and then to follow the same procedure of checking for irregularities before the final seal coat. One of the most common faults in construction is the tendency to use too much bituminous material. If the surface appears to be somewhat irregular in color, dry, and with even a number of small pittings, there is nothing to worry about, as it can be corrected easily with the final seal coat. On the other hand, a surface which has a very black, totally flushed appearance, is quite apt to be too rich, and, with the application of the seal coat, corrugations result. Prior to the seal coat, the "grade-rater" is again run over the surface to check all variations from standard, and all low places are again patched, using the minimum possible amount of bitumen. It is during this process of checking, adjusting and patching, that the greatest difficulty usually occurs with the contractor, and it is a time when the inspector needs to exercise all of his tact and patience, and, at the same time, be persistent and insistent that his instructions be carried out.

It is desirable that several weeks to several months elapse before the seal coat is applied. This gives an opportunity for settlement and compaction of the top course, and for all spongy, loose areas to whip out under traffic, thus leaving a solid surface on which to apply the final application of bituminous material. This final application is $\frac{1}{4}$ to $\frac{3}{8}$ gal. cold liquid asphalt, heated to about 100 deg. F. A sufficient amount of $\frac{3}{4}$ in. chips is applied to take up all surplus bitumen, and here again a new machine has been employed with satisfactory results. It is difficult (even with experienced operators) to apply chips from stock piles in an absolutely uniform manner. The several chip spreaders (which have been used) also produce results that vary considerably between the beginning and the ending of the load. To overcome this difficulty, an instrument has been devised which consists of a triangular frame made of steel, supported on wheels at each corner, with a cross member to which is attached a 10-ft. length of wire brooms. This cross member may be moved vertically to obtain any desired pressure of the brooms on the surface. It is operated immediately after the application of chips, producing a uniform distribution over the surface, thus overcoming any

tendency to bunching. While at first thought it would appear to be of minor importance, yet it contributes that extra refinement which results in a perfect surface.

To substantiate the conclusions set forth above, an experiment in construction was made during the past summer on U. S. Route No. 50 crossing the Allegheny Mountains. The section is 10 miles in length, the roadway having been previously graded and all drainage structures installed during 1923-24. Through the intervening years, constant maintenance has been carried on, so as to produce an entirely stable, graded-earth road. Contracts were let for this 10-mile section, divided in two 5-mile parts, one being for crushed stone base and the other for knapped stone base. Work proceeded simultaneously on the two sections and they were completed nearly at the same time. The grade was so laid as to require trenching from one end of the job to the other, thus putting the subgrade in thoroughly compacted material, maintaining the full roadway width, and, in addition, providing a surplus of berm material, so that no disfigured robbing of the slopes was necessary. The precautions set forth above, such as checking subgrade, stabilizing weak spots, placing the base course with carefully graded, uniform material, insistence upon thorough filling and rolling, checking with straight edge and template to the specification tolerance, were all carried out. Just prior to the completion of the base, a single contract was let for the full 10-mile length of top course, the type being "puddle macadam" of 3-in. compacted thickness, 18-ft. in width and with a 2-in. crown.

MATERIAL SPECIFIED FOR FUTURE WORK

This surface was laid under traffic, full width, with only a temporary barricade during the few minutes required to pour the first application of one gallon per square yard. The method of constructing "puddle macadam" has been previously described in a paper before the Highway Research Board in December, 1927. An experiment was made this summer, however, using asphalt primer coat for the initial application. It had been thought previously that insufficient penetration would be obtained by using this material, but on the contrary a penetration of $1\frac{1}{2}$ in. was had within two hours after application. Practically no cover coat was required, other than just enough to prevent picking up of the surface. Rolling was delayed for about an hour after application, and then made once over to obtain initial compaction. Rolling continued at intervals of several days thereafter, as the asphalt residue hardened, to keep the surface in shape. The results were very satisfactory, and this material will be specified for future work. The pavement was laid at the rate of about 1500 linear feet per day, and all of the precautions for testing the surface were carried on as above noted, the inspector being an unusually persistent individual, and contrary to the recommendation of one of our great industrial leaders, a man of about 60 years of age. He was on the job at 7 a. m., and did not leave until after the contractor left at night, a quality not always found with some of our younger college graduates. Traffic used this surface for several months prior to the seal coat, and while very little asphalt had flushed the surface, and a certain amount of shallow pitting occurred, this was not at

all harmful. The final seal coat consisted of $\frac{3}{8}$ gal. cold liquid asphalt, heated to maximum fluid condition, covered with approximately 20 lbs. of chips, and dragged with the steel broom as outlined above.

Shortly after this contract was finished, the remaining gap on U. S. Route No. 50 in Maryland was also completed, and immediately thereafter a large increase in traffic took place, so that an excellent opportunity has been had during the past two months to determine the riding qualities of the macadam section after being subjected to concentrated high speed traffic.

RESULTS AS TO SMOOTHNESS

For the past year our roads have been checked with a roughometer every two or three months to determine their relative smoothness and whether or not they are changing in their riding qualities. Previously built macadam with good, smooth riding surfaces have had an index of 100 to 150. Good riding concrete built in previous years has run between 75 and 125. These are pavements that two or three years ago were considered of good quality in smoothness and easy riding. The index for the 10 miles constructed with the methods outlined above is between 50 and 60 for the crushed stone base section, and from 55 to 65 for the knapped stone base. Even with every precaution, it is not possible to obtain the same smoothness with knapped stone, and it is probable that any deterioration in riding qualities will be more marked for the knapped stone than for the other. The index is arrived at from the amount of spring deflection over a mile of road at 25 miles per hour, so that the lower the index, the smoother the surface. Hundreds of miles of road have been checked with this instrument under all conditions of weather and temperature, so that good calibration is had, and while the results are not absolute, yet their comparative values are certain. Car speeds on this 10-mile stretch have run as high as 60 to 80 miles per hour on tangents, and while such speeds are by no means encouraged, yet the public derives a certain satisfaction in having pavements on which they can drive fast if desired. The many compliments received on this road further proves that the public is not so much interested in the type of road, as it is in its smooth riding characteristics, and that if a state desires to continue the use of the so-called cheaper types, then all it has to do is to use the same care and preparation as for the more expensive surfaces. The cost of good inspection is much less than poor inspection, for the saving is reflected during the subsequent years, in lower maintenance charges and the satisfaction derived from the excellence of the road.

PAINS-TAKING METHODS NECESSARY

The same principles apply to the construction of gravel, "retread," or even asphalt-treated shales. It pays to take pains with the smallest details. If, by following these methods, excellent, durable surfaces can be obtained at costs from \$5,000 to \$20,000 per mile, and then maintained thereafter at an annual expense which is less than the difference of interest charges on these types and the expensive pavements, assuredly

there will be much approbation from the public because of the much larger mileage from the same expenditure of funds. The public does not care what the road is made of but it does demand (and properly so) that these roads shall be smooth and safe.

DISCUSSION

CHAIRMAN WEDEKING: If any other of these twenty-three men feel that they have not had justice in this matter, we will continue this discussion a little while. This series of papers is now open for general discussion.

A DELEGATE: I would just like to ask one question. Where a road has been impregnated with calcium chloride to the extent of keeping down the dust, what is the effect of your prime, and will your retread system work just as well on a sand-clay or a gravel road where you had to keep the dust down with calcium chloride? Does that have any effect at all on the retread?

CHAIRMAN WEDEKING: All such questions we refer to Mr. Hinkle, in our department. (Laughter).

MR. HINKLE: The calcium chloride would have no detrimental effect on your retread top. I am not sure that it would not be beneficial. It would harden and solidify a certain amount of the old surface and certainly ought to add strength.

A DELEGATE: Information is wanted also as to whether or not the calcium chloride, giving a dampness to the road, keeping the dust down, would prevent your first penetration?

MR. HINKLE: The type of retread we build, which consists of a 1, 2 or 3-in. layer of loose material is put on the next year, so we do not need necessarily to penetrate except by the cold oil treatment, and in order to get loose material for that to act on, we apply that loose upon stone or gravel during the winter. I do not think it would be advisable to try to penetrate it that same year, but the following year there would be no objection whatever.

CHAIRMAN WEDEKING: You perhaps may have heard the statement, as I have heard it in the last few years, that "when we go over into Illinois, the state highway system is wonderful, but for God's sake don't get off the pavement." We have a man here this afternoon who tells me that he lives on an earth road that has been treated with oil, and that he drives on this road all the way from 60 to 75 miles an hour on the worst days in the winter. They tell me that he is a "whiz bang." He also says that he is a convention hound, so I think he will have something to tell us. Gentlemen, Mr. D. O. Thomas!

Oiled Earth Roads in Illinois

By D. O. Thomas, Belleville, Ill.

Superintendent of Highways, St. Clair County, Illinois

Our best thought and attention in the past has been given largely to the building of high-type primary roads, but more and more the secondary road is now receiving the earnest thought and study of the road builders of America. This secondary road system—that of the farm-to-market road—has, of course, a great deal larger mileage than the primary system and is not adequately financed and probably will not be, and since the traffic upon it does not require the high-type surface required on the primary system, we are studying and evolving low cost types of road surface which will take care of the traffic on these secondary roads. In some sections of the country the oiled earth road has its place as one of these low cost types of secondary road improvement.

Petroleum oil was used first in California some thirty years ago on the public highways, more as a solution of the dust problem than as a road builder. It was first tried in Illinois about twenty years ago, and its use has constantly increased since that time. The last available figures show that about 10,000 miles of earth roads are oiled annually in Illinois, using about 45,000,000 gallons of road oil, at a cost of about \$2,500,000 a year. I suspect there has been no material increase in these figures in the last few years, and I believe that may be taken as the average annual performance in Illinois.

OILED ROADS ON ILLINOIS SECONDARY SYSTEM

This oil is used by counties, townships and road districts on the secondary roads, and by incorporated cities and villages on some of their streets. The State Highway Department of Illinois does not carry on any road oiling operations on the highways under its jurisdiction. The main reason for the extensive use of road oil in Illinois, is the lack of local deposits of gravel and stone suitable for road purposes. In the portions of the state where these materials are available, the use of road oil is limited.

Where other materials are not available, and with the limited funds at hand, the use of road oil seems to be the best means of alleviating intolerable road conditions for a part of the year at least. The continued use of this material is evidence that the road user is fairly satisfied with the results obtained and is willing that the expenditures for road oiling be continued.

The large amount of road oil used in Illinois has attracted the attention of those interested in road building in this state and there has been considerable cooperative experimental work and study in order to find the best methods of doing the work and to select the most suitable type of road oil adapted to Illinois soil. Studies and experiments have been carried on by the University of Illinois and the Illinois Division of Highways in cooperation with the highway superintendents of some of the counties where large quantities of oil are used annually.

The following observations as made by the Illinois Division of High-

ways are the results of many years of experience with this work and of the studies and experiments that have been made:

Oiled earth roads, under the freezing and thawing and other conditions existing in Illinois, are undoubtedly the least permanent of any type of road built, and the results obtained by the use of oil are less certain than for any material in common use. Therefore, expenditures for earth road oiling should be charged entirely to maintenance, with little if any expectation of getting permanent benefits. Many doubt the wisdom of spending money for oil because of the temporary nature of the improvement, but experience has shown that the oiled earth roads of Illinois are much better than untreated roads throughout the year and are in such popular favor that there is little likelihood that oiling operations will be stopped unless some better substitute is found. If expenditures for oil are judiciously directed and care is used in applying the oil and maintaining the surface, the cost may be justifiable under Illinois conditions.

CAUSE OF DEFECTS IN OILED ROADS

The faults of oiled earth roads, such as their tendency to become pitted and to break up easily under adverse weather conditions, are not due entirely to inherent defects of this type of road. Many counties and townships make a practice of laying out a greater mileage of roads than their funds will permit them to care for properly. As a result, the preparation of the road bed to receive the oil is neglected, the amount of oil applied is inadequate, and the oiled surface is given little or no maintenance. If road oiling programs were kept within the limits of the available funds, better oiled roads would probably result. Roads in poorly drained areas which are known to possess an unstable subsoil are not likely to make successful oiled roads. Furthermore, oiling does not produce good results either on roads which carry light traffic or those carrying exceedingly heavy traffic. If roads unsuited for oiling were excluded and oiling programs were confined to roads upon which traffic conditions had been studied and which have had suitable preparation, better results would be obtained. However, it may be desirable to maintain such roads by means of oil until such time as they can be improved more permanently. The surface of a road carrying extremely heavy traffic may frequently be improved by the application of a sufficient quantity of oil and the right kind of maintenance afterward.

Pneumatic tires exert a beneficial effect upon an oiled earth surface because they tend to smooth and compact the surface. It is doubtful whether a satisfactory surface can ever be formed with oil without a certain amount of motor traffic. Steel tires, especially if narrow, quickly disintegrate and destroy an oiled surface. Where the traffic on a road exceeds 200 or 300 vehicles per day, the normal steel tired traffic seldom exceeds 10 to 15 per cent of the total traffic, and as long as such proportions are maintained, motor traffic will tend to neutralize the rutting and other detrimental effects of steel tired traffic. On many roads, however, the proportion of motor traffic to wagon traffic is seldom sufficient to develop an oiled surface or to keep it compacted. Therefore, it is poor economy to oil them. The most important part of road oiling is the proper preparation of the earth road before oiling.

I may say here that the success of an earth road is 90 per cent preparation of the earth surface and 10 per cent the kind and amount of road oil put upon this surface. I do not propose to tire you with details as to the preparation of an earth road, but if you want a successful oiled road you must have, of course, a properly graded and drained earth road of the proper cross-section with the proper crown. The earth must be compacted and smooth and free from dust, and a crown of about a quarter ($\frac{1}{4}$) of an inch per foot of width of roadway which will insure transverse drainage and yet not interfere with safety and comfort of travel.

The oiled portion of the road should be at least 16 feet wide as this width is sufficient to accommodate the ordinary traffic and discourage the practice of driving with one set of wheels on the unoiled portion. The last operation in the preparation of an earth road just previous to the application of the oil, is the removal of the dust or loose dirt remaining on the surface. It is important that this detail should not be overlooked because even a small amount of dust interferes with the penetration of the oil and causes the fresh oil to pick up under the wheels of the oil distributor. This dust or loose dirt should not be left in windrows at the side of the road as an obstruction to drainage, but should be feathered out over the shoulder. If the earth is dry and the dust excessive and its removal would leave a rough, uneven surface, the oiling should be postponed until the dust has been settled by rain.

SALVAGING BROKEN SURFACES

The preparation of an old oiled surface which has partially broken down presents some difficulties and the best method of handling such a surface is to scarify it and regrade it before the new oil is applied. If an oil of a moderate specific viscosity has been used, scarifying may not be necessary and the oiled surface may be worked early in the spring and brought to a reasonable shape for reoiling with ordinary maintenance equipment. If such a surface is given attention early in the spring, a great deal of trouble later on in the season can be avoided.

Two applications of road oil are necessary each season to keep an oiled earth road in good condition throughout the year. The following quantities of oil have been found most satisfactory for the soil and climatic conditions existing in Illinois:

(a) For roads not previously oiled or on which the old oil has disappeared, one treatment, amounting to three quarts per square yard, applied to the road before July 15, followed by one treatment of one quart per square yard applied about September 1, or a seasonal total of one gallon of oil per square yard.

(b) For roads which have a serviceable oiled surface remaining from the previous year, one treatment, amounting to from one to two quarts per square yard, applied as soon after April 1 as the road can be made ready, followed by one treatment of one quart per square yard applied about September 1, making a total seasonal application of from two to three quarts per square yard.

Friable, silty and timber soils require heavier oil treatments than clay soils. Very steep hills should not be oiled if enough gravel or stone can be secured to construct a gravel surface.

SHIPPING AND STORAGE OF OILS

Road oil is usually shipped direct from the refineries to the users in 8000-gallon capacity available for shipping road oil. Since freight in 6000-gallon cars, but as a rule there are few tank cars smaller than 8000-gallon capacity available for shipping road oil. Since freight charges must be paid on 98 per cent of the shell capacity of a tank car, regardless of the actual content, it is not advisable to order oil in less than 8000-gallon quantities unless it is known that the company can furnish it in the smaller sized cars.

It is the general practice in Illinois to order the oil as it is required and use it direct from the cars, as very few counties or townships have any facilities for storing road oil. This practice has the following advantages:

- (1) It requires less handling of the oil.
- (2) Every railroad siding can be utilized as a base for oiling operations, thus reducing to a minimum the length of haul in the distributors.
- (3) It is easier to heat the oil in the cars than in storage tanks.

The principal disadvantage is that weather or other causes may delay the spreading of the oil and cause demurrage charges to become a serious item of expense, but it does not seem likely that the practice of storing oil will become general because of the storage costs and because of the advantages given above. However, every county or township should store a small quantity of oil for maintenance and repair work.

It is convenient and economical to operate oil distributors in fleets of two or three, because one distributor working alone is usually too slow. Tank cars must be unloaded promptly after delivery to avoid demurrage. It usually is desirable to expedite oiling operations when weather and road conditions are favorable, and it is desirable to reduce the time that a road must be closed to a minimum so as to cause the least possible inconvenience to the public.

USE OF DISTRIBUTORS OUTLINED

There are two general classes of oil and asphalt distributors on the market, one being designed to spread bituminous materials which require heating to high temperatures, and the other to spread materials which may be spread cold or may require but slight heating. This latter type is used for oiling earth roads. It is not necessary for distributors to be equipped with heating apparatus. In fact, such equipment is undesirable because it adds unnecessarily to the weight. Distributors should be so equipped that the rate of discharge can be controlled accurately to the required quantity per square yard. Moderate sized distributors having a capacity of from 600 to 750 gallons are preferable. The larger distributors are so heavy when loaded that they tend to rut and deform the prepared surface. Distributors should be

equipped with adjustable length nozzle bars to spread any desired width from four to twelve feet.

Equipment for heating and pumping oil consists of a steam tractor or portable boiler for generating steam and a rotary pump for pumping the oil. A good thermometer should be provided for taking the temperature of the oil. The oil must be heated until it is thin enough to spray uniformly without stringing or clogging the spraying nozzles of the distributors. This temperature will usually be from 130 deg. Fahr. to 175 deg. Fahr., depending upon the grade of oil and the air temperature. Nothing is gained by heating oil above the temperature at which it spreads well. Steam for heating may be generated by means of a portable boiler or a steam tractor. A pressure of 100 to 125 pounds is desirable.

HEATING THE OIL IN TANK CARS

Most road-oil cars are equipped with steam heating coils. It requires, however, about fifteen hours or more to heat a car of oil to the required temperature when these coils are used. The oil can be heated in a fraction of this time by injecting a jet of dry steam directly into the oil through the dome of the car. Furthermore, a current of steam of this kind not only reduces the heating time, but also heats the oil thoroughly and mixes it in a very desirable manner. A small amount of water, usually 2 or 3 per cent, is introduced into the oil in the form of condensed steam when steam jets are used, but this amount of water is not objectionable.

When the temperature of the oil is raised from 70 deg. Fahr. to 160 deg. Fahr., it expands about $3\frac{1}{2}$ per cent, and if 3 per cent of water is condensed into the oil during the heating, the total expansion will be around $7\frac{1}{2}$ per cent, or 750 gallons for a 10,000-gallon car. While most cars of oil when received are usually short of being filled and will allow for considerable expansion, care must be taken when heating not to force the oil out of the dome by this expansive action. It is desirable and often necessary first to remove a distributor load of oil before raising the temperature of the remainder for spreading. The first distributor of oil can be brought to the desired temperature in a few minutes by injecting a little steam into it in the same manner as in the car.

APPLYING THE OIL TO THE ROAD

It is not advisable to oil a road without first closing it to traffic even though it is frequently done. Under most conditions, even a few vehicles passing over a freshly oiled road will cause permanent damage to the surface. This is particularly true of a road being oiled for the first time. Sometimes a single application of oil can be applied on a road which has been previously oiled without closing it to traffic and without much detriment. Fresh oil, however, is extremely slippery and dangerous to traffic and the majority of the traveling public seriously objects to traveling on it. It usually is advisable to close a road and provide a detour out of consideration for the safety and comfort of traffic if for no other reason. There might be objection to this because the closing of roads and marking of detours involve considerable expense, in as much as it usually takes one man's time to look after detour signs,

barricades and lights, besides possibly two or more men for duty as guards. The best results are obtained when the applications of oil are made in the daytime during clear, warm weather. In case of rain during the night or following morning, considerable of the oil may be washed into the ditches and lost but this must be chanced. Oil will not penetrate a previously oiled surface which has become matted or oil soaked, regardless of the weather conditions. Therefore, when reoiling such a surface the new application of oil should be given a covering of earth as described below. In fact, any oil not absorbed by the road surface at the end of 48 hours should be covered in order to prevent its being carried away by traffic and lost.

A light covering of earth, just sufficient to absorb excess oil, will make a smoother surface than can be obtained in any other way. There are always slight pits and irregularities in any previously oiled surface which is to be retreated and when the oil is applied the excess tends to flow toward any pits and depressions which may be present. When dirt is put on by the method described in the next paragraph, it mixes with this surplus oil, completely filling depressions and producing a most excellent surface. Further, such covering cuts down the time that a road must be closed for oiling. It usually is possible to apply the oil, cover it and open the road to traffic on the same day. Oil which does not penetrate quickly is always subject to being lost in case of rain. Covering the oil prevents any losses from this source.

COVERING THE OIL WITH EARTH

Roads which have been oiled for a number of years or which have received two or three heavy treatments are often too rich in oil on the surface, or, as an asphalt man would say, they are "too fat." Such roads, if traffic on them happens to be heavy, tend to corrugate much in the same manner as gravel roads corrugate when traffic exceeds a few hundred vehicles per day. The surface of an oiled earth road will never become too rich in oil, if the oil is covered with earth after it is applied, and corrugations will not develop.

A sectional blade maintainer is the best type for this work, but an ordinary patrol blade or any other blade maintainer may be used. Two men with a two or five-ton crawler-type tractor and a sixteen-foot jointed-blade maintainer can cover per day from four to six miles of oil which has been spread sixteen feet wide. Three rounds are usually necessary to cover the oil completely. The first round is to procure the dirt which should be scraped from the shoulders and deposited in windrows on either side of the road just outside of the strip to be oiled. This round must be made before the oil is spread, otherwise the oil will make the road so slippery that it would be impossible to cut the dirt from the shoulder. After the oil has been spread, the dirt is spread over the entire oiled surface. This operation usually can be accomplished in two rounds.

It is important that no larger quantity of dirt be used than is required to absorb the surplus oil because a greater amount will tend to bury the oil and defeat the purpose of the oiling. The road can be opened to traffic as soon as the oil has been covered.

A well shod heavy drag or a light grader usually is heavy enough properly to maintain an oiled earth road. Earth from the shoulders should never be dragged on to the oiled portion of road under any circumstances. Plain dirt will not bond with the oiled surface. It will be dusty in dry weather and will be muddy and slippery in wet weather. In case the shoulders of an oiled earth road need attention, they should be dragged separately.

Snow is one of the worst enemies of an earth road and is the frequent cause of failure of an oiled, earth-surface road. It should be removed after every storm.

LACK OF COUNTY ROAD OIL SPECIFICATIONS

Specifications for road oil are of a technical nature and the average county or township road official lacks the necessary data and information to enable him to prepare such specifications. The Illinois State Division of Highways has prepared a set of road oil specifications in order to meet the needs of these officials and practically all of the oil used on earth roads in Illinois has been purchased under these specifications. The use of this single standard set of specifications has done much to promote economy and uniformity in the road oil market as well as to maintain the quality of road oil supplied.

All road oil purchased by the county and township officials is inspected by the State Division of Highways either at the refinery or from samples taken from the cars after shipment. Road oils expand at the rate of about 1 per cent for each 25 deg. Fahr. increase in temperature and all measurements are based upon the volume of the oil at 60 deg. Fahr.

The solid residue or so-called "asphalt" content of road oils is much misunderstood by both the sellers and users of road oils. In fact, most road oils do not contain asphalt in the sense that asphalt is actually used in their preparation. When a road oil is evaporated to a solid consistency in the laboratory it yields a solid residue which may or may not be asphalt. Certain asphalt-based petroleums from California, Mexico and Gulf Coastal fields yield residues upon evaporation which consist of practically pure asphalt, but most of the road oils used in Illinois are obtained from domestic paraffin and semi-asphaltic petroleums which yield residues more closely resembling wax than asphalt. Experience has shown that the paraffin and semi-asphaltic oils which yield waxy residues are in every respect equal, if not superior, to the pure asphalt-based oils for oiling earth roads under the conditions existing in Illinois. The black, oily, asphalt-like surface which, under certain conditions, develops on oiled earth roads, and which is often attributed to the asphalt contained in the road oil, is obtained as frequently on roads oiled with paraffin-based oils as it is on roads oiled with asphalt-based oils.

ROAD OIL SPECIFICATIONS IN ILLINOIS

At best the test for solid residue as ordinarily interpreted is only a rough indication of the consistency of an oil, a quality which might be expressed much better by the standard specific viscosity test. For these reasons the solid residue, or "asphalt," requirement has been dropped from the Illinois specifications and all the oils are graded upon a basis of their specific viscosities at 60 deg. C.

The Illinois specifications for road oil provide for five different grades of oil, as follows: (a) E-1 Specification provides for a light grade asphalt-based oil with a specific viscosity at 60 deg. C, of from 8 to 16. (b) E-5 provides for a heavy grade asphalt-based oil with a specific viscosity of 16-1 to 28. (c) E-2 provides for a light grade semi-asphaltic oil of a specific viscosity of 8 to 16. (d) E-3 provides for an intermediate grade of semi-asphaltic oil of specific viscosity of 16.1 to 28. (e) E-4 provides for a heavy grade semi-asphaltic oil of a specific viscosity of 28.1 to 42.

COSTS ARE FOUND TO VARY

Most of the road oil used in Illinois is of the E-3 grade of semi-asphaltic oil with a specific viscosity, at 60 deg. C., of 16 to 28, although on new roads which have not been oiled previously, a first treatment of E-2 oil sometimes is used with a final coat of E-3 oil applied in the early fall.

Costs of this work, of course, vary considerably, but the average cost per gallon of oil applied to the road in accordance with the Illinois state specifications is from 5c. to 6c. per gallon, about $1\frac{1}{2}$ c. of this total amount being the cost of the heating and application of the oil.

The main thing about constructing the oiled road is that of getting the dirt road ready and putting on the oil. If you put on enough oil to maintain it right, you will have a fairly good road. In Illinois we seem to be fairly well satisfied with oiled roads and earth roads, for want of something better.



R. M. SMITH
DEPUTY MINISTER OF HIGH-
WAYS, ONTARIO PROVINCE,
CANADA

THIRD SESSION

OCTOBER 30, 1929, 9:30 O'CLOCK A. M.

R. M. SMITH, DEPUTY MINISTER, ONTARIO, CANADA, DEPARTMENT
OF PUBLIC HIGHWAYS, PRESIDING

CHAIRMAN R. M. SMITH: The meeting will please come to order. While I am listed in the program as Deputy Minister of the Department of Public Highways, an election is taking place in Ontario today, so that tomorrow my title may be changed. (Laughter.) Of course the Province of Ontario appreciates the honor conferred on us in asking me to act as chairman at this session of the conference. In a small way, we are doing something in connection with the laying of asphalt this year. We are constructing approximately 100 miles of what we call asphalt macadam surfaces, entailing the use of approximately 450,000 tons of mixed material, in addition to which we are using a considerable amount of asphalt for surface treating, retread construction and other types of pavement. The first paper on this morning's program is that of "Asphaltic Treatment of Earth Road Surfaces in Fresno County, California," to be presented by Mr. Chris. P. Jensen, county engineer of Fresno County. In the absence of the author of the paper it will be read by Mr. W. E. Rosengarten of the Asphalt Association.

Asphaltic Treatment of Earth Road Surfaces in Fresno County, California

By Chris. P. Jensen, M. Am. Soc. C. E., Fresno, Calif.

County Surveyor, Fresno County, California

The development of what locally is termed "oiled road surfaces" in Fresno County is the result of some twenty-five years of effort and experience. It had its inception while horse-drawn vehicles still represented 90 per cent of the general traffic, and at a time when the development of the mineral oil fields in Fresno and other counties of the State of California had reached considerable proportions. Observation of the effects of traffic over stretches of road upon which oil had been spilled or distributed near oil well operations was responsible for the initial use of oil on road surfaces and the belief that such a procedure would be a very economical and efficient method of preventing the customary dust nuisance as well as providing a smoother and firmer surface for traffic.

While the first applications of road oil were restricted naturally to the more important thoroughfares running through the county, the comfort, convenience and economy of such a treatment caused an ever increasing demand for an extension of the use of road oil to roads other than the main thoroughfares. The governing body of the county, therefore, continued to increase the mileage of oiled roads from year to year, and at the

present time the county has to its credit approximately 3000 miles of oiled road surfaces, constructed and maintained at no greater cost than that of maintaining an ordinary earth surface from year to year. During the last eight years, the annual purchase of oil by the county for road oiling purposes has reached a total of approximately one hundred and fifty thousand (150,000) barrels, of forty-two (42) gallons each.

LIMITATIONS IN THE USE OF ROAD OIL

Fresno County has a wide variety of soil conditions, including pure sand, sandy loam, red loam, alluvial, adobe, dry bog and soils impregnated with what commonly are designated as "black alkali," and "white alkali."



CHRIS. P. JENSEN
COUNTY ENGINEER, FRESNO, CALI-
FORNIA

Naturally, the oiling operations must be varied and adapted to each individual soil condition. By a proper analysis of all soil conditions, coupled with the results of accumulating experiences, the oil treatment has been eminently successful on all soils, with the possible exception of soils impregnated with white alkali. Alkali soils present a problem beyond the influence of anything other than extremely heroic treatment, including the stabilizing of the subgrade for a considerable depth by the importation of rock. This soil is of such a vicious character that even heavily reinforced concrete road surfaces are not immune from its destructive effects.

On adobe or dry-bog soils, the efficiency of oiling operations materially is enhanced by the use of sand or small river gravel applied to a depth of from 4 to 12 inches, according to conditions of subgrade saturation. On all other soils, the application of oil is made without the assistance of any other stabilizing or reinforcing materials.

Generally speaking, the road surfaces in Fresno County, treated with road oil, will carry a mixed traffic of fifteen hundred (1500) vehicles per day. The maximum load limit on any vehicle in California is twenty-two thousand (22,000) pounds on four wheels, or thirty-four thousand (34,000) pounds on six or more wheels.

LOCAL ROAD OIL SPECIFICATIONS

As already indicated, certain soils, particularly if subject to excessive moisture or not well drained, have not sufficient stability to support this traffic without the use of other materials such as sand, gravel or crushed rock in sufficient quantities to overcome the instability of the foundation and to support the oiled earth surfacing and its superimposed traffic.

Until 1921, the oil used for road purposes was a natural crude oil, as taken from the wells, and without any distillation or refinement. A selection of the oil to be used was made usually from wells discharging

oil of approximately 14 deg. gravity, Baume scale, carrying 65 per cent of bitumen or asphalt. During the last few years a refinery residue has been specified, carrying an asphaltic content of 65 to 73 per cent. The results obtained practically have been identical in the use of either of the above mentioned oil products, but at the present time we are inclined to the use of a road oil carrying not more than 65 per cent of

PHOTOGRAPH No. 1



ROADWAY IN FRESNO COUNTY, CALIFORNIA, AFTER A LIGHT SCARIFYING PREPARATORY TO RECEIVING A DISTRIBUTION OF OIL

bitumen, for the reason that if the heavier oil is used and after two or three years of such applications, the road surface becomes so hard and tenacious as not to render it readily susceptible to scarification and smoothing.

PORTABLE HEATING PLANTS USED

The oil is delivered in railroad tank cars, and before being applied, must be heated to a temperature of approximately 200 deg. F. For this purpose the county employs the use of twenty horse power boilers with sufficient retorts to bring the oil to the required temperature. These heating plants are made portable so as to be taken readily to any delivery point on the railroads. For use within a radius of 10 miles of Fresno City, the county has a fully equipped and standard steam heating plant with a reservoir capacity of five railroad tank cars. At the present time the cost of oil at the well is fifty-two and one-half cents (52½c.) per barrel of forty-two (42) gallons. Freight charges bring the total cost of the oil at various delivery points in Fresno County to one dollar (\$1) per barrel.

PHOTOGRAPH No. 2



ROAD IN FRESNO COUNTY, CALIFORNIA, SCARIFIED TO A DEPTH OF SIX INCHES IN ORDER PROPERLY TO ELIMINATE CHUCK-HOLES. READY TO RECEIVE A DISTRIBUTION OF OIL

The making of a satisfactory oiled road surface is a matter of gradual development. Unless exceptionally favorable conditions prevail, a satisfactory surface cannot be obtained until the second year, or until four or five applications of oil have been made. Each application of oil is made at the rate of approximately three-fourths ($\frac{3}{4}$) of a gallon per square yard of surface, varying slightly according to soil conditions. In new road construction, two, or even three, applications of road oil can be applied during one year. In order to take advantage of weather conditions, the county restricts its oiling season to the months of June, July, August and September. Operations during the winter months do not prove to be as economical nor do they produce as favorable results as operations undertaken during the summer months.

GRADING METHODS DESCRIBED

The first requisite in new road construction, as in other methods of construction, is to bring the road to its proper crown, grade and alignment. In Fresno County, except in the mountainous districts, the grading of a road is a very simple matter, the only implements required being a tractor and grader of sufficient power for its purpose. Usually a 60 hp. caterpillar and 10 or 12-ft. blade, is used. After the road has been brought to its proper grade and cross-section, a small amount of the earth is bladed to the edges of the portion to be oiled. Oil is then spread on the surface of the roadway at the rate of approximately three-fourths ($\frac{3}{4}$) of a gallon per square yard, and immediately covered with the earth previously bladed to the edges. This covering is done by means

of power graders, or by caterpillar-drawn graders. The influence of the summer heat tends to draw the oil upward, particularly so when traffic is given access to the roadway, so that after a few days under traffic, the oil gradually works to the surface, giving the road surface a smooth, black appearance, similar to the surface of an asphalt pavement. Should it appear that sufficient covering had not been spread over the oil to prevent free oil from coming to the surface, additional covering material is bladed in from the shoulders or borrow pits. Any excess of covering material will be thrown aside rapidly by moving vehicles.

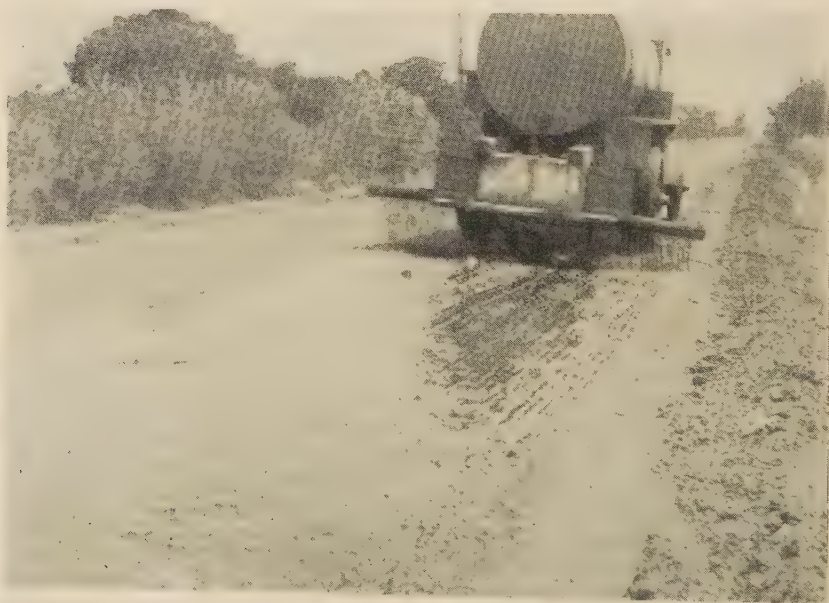
SECOND APPLICATION OF OIL

As soon as the traffic begins to break through the first application of oil, the surface is scarified and pulverized to a depth of 2 or 3 in. and a second application of oil, at the same rate, is then applied in similar manner to the first application. This procedure is repeated from time to time during the first two years, until the entire roadway has assumed a proper condition of stability. Under ordinary conditions of soil, four or five applications will be found sufficient.

PLANING OF THE SURFACE MAY BE NECESSARY

It has not been found necessary to make use of a roller in any of these operations, it being a peculiarity of oiled earth surfaces that the solidification of the surface material is effected more rapidly and perhaps more efficiently by traffic than under the action of a roller. During the first two or three months after the application of oil, the volatile oils gradually evaporate and coincidentally, the surface becomes gradually solidified or

PHOTOGRAPH No. 3



OIL TRUCK SPREADING OIL ON HIGHWAY, FRESNO COUNTY, CALIFORNIA, HIGHWAY DEPARTMENT

PHOTOGRAPH No. 4



HIGHWAY IN FRESNO COUNTY, CALIFORNIA, SHOWING THE EXPEDITIOUS MANNER IN WHICH THE OIL IS COVERED BY THE USE OF ONE-MAN POWER GRADERS

hardened. During this period of solidification it may be necessary occasionally to scratch and plane the surface with a scarifier and grader in order that when final solidification takes place in the early winter temperature, the surface may be true to cross-section throughout the winter. It scarcely ever becomes necessary to do any maintenance work on oiled surfaces during the winter and spring.

DISTRIBUTION OF THE ROAD OIL

Oil is distributed from tank wagons having a capacity of approximately twelve hundred (1200) gallons, by a gravity flow, through perforated distributor pipes covering a width of 10 ft. of roadway in one application. The oil should have a temperature of not less than 200 deg. F., for proper distribution. Oil distribution from tank distributors equipped with power sprays, has been used, but the additional advantages derived from distribution from power sprays have not been sufficient to warrant their use.

The total cost of applying the oil, resolved into a gallon unit cost, including preliminary blading, spreading, covering and subsequent scarifying and planing, but not including the original construction of the foundation grade, will average three cents (3c.) per gallon for each application. One mile of roadway treated with oil to a width of 10 ft., therefore, would cost one hundred thirty-two dollars (\$132) for each application. Assuming that the roadway is brought to a stabilized condition in four applications of the oil, we have a total cost of five hundred

twenty-eight dollars (\$528) per mile, which represents what properly might be termed the end of the construction period, and the commencement of what properly might be termed the maintenance period.

MAINTENANCE OF OILED ROADS

During the first three or four years of service, a newly constructed oiled road is carefully watched, and special localized treatments are given according to weaknesses and peculiarities developing during the process of stabilization and evaporation of volatile oils. No predetermined or uniform treatment of maintenance work can be specified, due to the lack of uniformity in soil characteristics and drainage conditions. Unlike a uniformly constructed surface involving the use of rock aggregates in proper proportions, and binders, the nonuniformity of the earth structure permits the oil surface to shift and sometimes to take on a corduroy or wavy surface. Correction of this peculiarity is made by the use of a scarifier and blade from time to time as may be found necessary. After a road has been constructed for a number of years, and becomes stabilized under the action of traffic, the oil will not generally need to be renewed oftener than once every two years.

During the spring the road superintendents make a complete survey of the oiled surfaces, and a program of maintenance is outlined for each road, effective during the summer and autumn months. In some cases it will be determined that the road will need nothing further than a

PHOTOGRAPH NO. 5



ONE-YEAR-OLD ROADWAY WHICH HAS JUST BEEN SCARIFIED SLIGHTLY AND WHICH WILL RECEIVE NO FURTHER OIL TREATMENT AT THIS TIME. FRESNO COUNTY, CALIFORNIA, HIGHWAY DEPARTMENT

PHOTOGRAPH NO. 6



OIL HEATER USED BY FRESNO COUNTY, CALIFORNIA, HIGHWAY DEPARTMENT FOR HEATING ROAD OIL IN TANK CARS PREPARATORY TO DISTRIBUTION ALONG THE ROAD

planing of the surface. In other cases, it will be determined that a single application of oil should be used; and in still other cases, where the traffic has been heavy, or soil and subgrade conditions unstable, it will be determined that the road should receive a complete scarification and reoiling.

Where only a planing of the surface is deemed necessary, the road is given a light scarifying and blading one or more times during the eight months surrounding the summer season, as may be required by conditions. The material loosened by this operation is spread uniformly over the surface by the grader, and immediately is compacted and united with the old surface under the action of traffic.

MAINTENANCE OPERATIONS DESCRIBED

When it is determined that the oil cake has become so old as to have lost its resiliency and another application of oil is desirable to renew the life of the surface, the roadway is scarified to a depth, approximately, of 1 in., the loose material is bladed to the edges of the roadway and an application of oil, at the rate of from one-third ($1/3$) to three-fourths ($3/4$) of a gallon per square yard, according to conditions, is distributed over the surface, after which the loose material previously bladed to the edges is bladed back over the fresh oil, and the road immediately thrown open to traffic.

Should it be determined that a roadway has become so badly rutted as to render correction by the two former methods impracticable, the roadway is scarified to the depth of the chuckholes, and all the loose

scarified material thoroughly pulverized. A portion of the upper surface then is bladed to the edges of the roadway, for subsequent use as cover material, oil is spread over the surface at the rate of three-fourths ($\frac{3}{4}$) of a gallon per square yard, and the earth previously bladed to the edges is bladed back over the freshly oiled surface. The cost of the operations described above, will range from fifty dollars (\$50) per mile in the case of a simple scarification and planing, to a maximum of two hundred dollars (\$200) per mile in the case of a roadway which has completely to be pulverized and rebuilt.

OIL SHOULDERS FOR HARD SURFACED HIGHWAYS

The usual maintenance equipment employed in Fresno County, consists of 60 hp. caterpillars, Haynes improved road machines (which scarify, pulverize and blade the material practically in one operation), gravity oil-tank spreaders mounted on trucks, and power graders for covering the oil. Work is arranged in such a manner that freshly applied oil is covered entirely during the same day as applied, so as to cause a minimum of inconvenience to traffic.

The oil roads in this community are held in such high repute by the people, that it was found advisable to apply our oiling methods to shoulders of the bonded highway system. This work is done in a manner similar to that described for the ordinary roads, and at a similar unit cost. The result of such treatment on the highway system, in effect, is the equivalent of widening the highway itself, as under the present standard of maintenance the line of demarcation between hard surfaced

PHOTOGRAPH No. 7



EFFECT OF OILING SHOULDERS OF ROAD ADJACENT TO A HARD SURFACE PAVEMENT.
FRESNO COUNTY, CALIFORNIA, HIGHWAY DEPARTMENT

pavement itself and the oil shoulders is scarcely discernible. The shoulders are usually oiled to a width of five feet.

EXPLANATION OF PHOTOGRAPHS

Photograph No. 1 shows a roadway after a light scarifying preparatory to receiving a distribution of oil. Photograph No. 2 shows a roadway which it had been found necessary to scarify to a depth of 6 in. in order properly to eliminate chuckholes, and which is ready to receive its distribution of oil. Photograph No. 3 shows an oil truck spreading oil. Photograph No. 4 shows the expeditious manner in which the oil is covered, by the use of one-man power graders. Photograph No. 5 shows a roadway one year old which has just been scarified lightly, and which will receive no further oil treatment at this time. Photograph No. 6 shows one of the county's oil heaters, used for the purpose of heating the oil in railroad tank cars, preparatory to distribution along the road. Photograph No. 7 shows the effect of oiling the shoulders adjacent to a hard surfaced pavement.

In connection with the presentation of the slides as outlined above, Mr. Rosengarten made the following statement:

MR. W. E. ROSENGARTEN: In Fresno County, Cal., they are applying much more oil than is the practice in Illinois, as described in the paper by Mr. Thomas. The use of the greater quantity of oil seems to make it possible occasionally to pass a year without oiling. The oil is heated by passing the steam through coils in the car, whereas in Illinois they introduce a steam jet into the dome, and in that way they are able to heat the oil more quickly than is possible with the coils. It is interesting to note how the oil treated shoulders blend in with the rest of the pavement. This, I think, is a practice that could well be followed by other states and would eliminate that sharp edge which we find along some paved surfaces and which is really dangerous.

DISCUSSION

CHAIRMAN SMITH: You have heard the address, as given by Mr. Rosengarten for Mr. Jensen. I am sure you must have found it very interesting. In the Province of Ontario we have oiled the dirt road, as you have in many of the states. The dust nuisance makes a dangerous condition on highways and it must be eliminated, because of the fact that traffic is becoming so heavy on the main traveled roads that more motor cars are being forced into the back roads. And so I think this paper that has just been presented is most interesting. I am sure that Mr. Rosengarten is familiar with the subject and will be very glad to answer questions and discuss this subject further during the time at our disposal. Is there any one who would like to start the discussion in connection with the paper just presented? I am sure Mr. Rosengarten will be very glad to answer any questions and give any information desired.

A DELEGATE: I would like to ask Mr. Rosengarten if they give the shoulders the same treatment as the road?

MR. ROSENGARTEN: It is my understanding that the same treatment is given the shoulders as is given to the roadway. Since the traffic is light, consisting only of the occasional vehicle that goes off the roadway, it may not be necessary to use quite so much oil or to oil so frequently.

CHAIRMAN SMITH: Are there any other questions?

PROF. F. H. ENO, COLUMBUS, OHIO: I would like to ask Mr. Rosengarten one question in regard to the difference in the action taken, as given in this paper and in the one by Mr. Thomas. Mr. Thomas spoke of causing the road to roll. Is the character of the oil sufficiently different to make any difference in the use of the oil or the amount of it?

MR. ROSENGARTEN: I will ask Mr. Hubbard to answer that as he has only recently returned from an inspection trip in the western states.

MR. PREVOST HUBBARD: In Fresno County, where I had an opportunity to inspect an oiled earth road, the character of the soil was considerably more sandy than in Illinois, but Mr. Jensen has obtained some of the most remarkable results with his oiled earth road treatment of any results I have seen anywhere. Some of his pavements have all the appearance of a higher type of construction, are just as durable and have given excellent service.

PROF. ENO: Does he attempt to get any metal into the wearing surface?

MR. HUBBARD: Only under the conditions stated in his paper.

PROF. ENO: The reason I asked this question was that using more oil in that character of soil, it seems to me, would be the proper thing to do. It gives the plastic, adhesive qualities needed in a more porous, sandy soil. My own observation, from an inspection of these roads, is that California has used oil for a great many years. I have seen oiled roads in San Diego and Pasadena and all through the southern part of the state, which they oiled 6 or 8 in. in depth. They look like an asphalt pavement, except that they are a little more sticky on top for rubber tired vehicles. It does seem that, where the oil is of the right kind, a greater amount of oil can be used there than in the case of gumbo soil.

A DELEGATE: I think it might be interesting to know what kind of oil, Mexican, or what other kind, was used there to get these results?

MR. HUBBARD: The only oil used there is the California oil.

CHAIRMAN SMITH: Our time is passing, gentlemen. If there are no other questions and no further discussion, the next paper will be presented by Mr. F. C. Lang, testing engineer of the Minnesota State Highway Department, on the subject of "Blotter Treatment of Gravel Roads in Minnesota."

Blotter Treatment of Gravel Roads in the State of Minnesota

By F. C. Lang, St. Paul, Minn.

Engineer of Tests and Inspection, Minnesota Highway Department and Associate Professor of Highway Engineering, University of Minnesota

The Minnesota bituminous surface treatments were started originally for the purpose of improving two unsatisfactory but entirely different road conditions. First, on sandy soils where the road bed and surface gravel were both deficient in binder, resulting in a loose, uncompacted road surface, particularly bad in dry weather, and second, on heavy clay and gumbo roads where gravel surfacing had to be hauled long distances, so that it was very expensive and, when placed, was effective only a short time, due to the fact that the granular material gradually sank into the heavy soil. Such roads were worst during wet weather. The treatments have given such general satisfaction that other types of roads have been treated and at present Minnesota has 784 miles of such roads on a primary trunk highway system of 6946 miles. There are also 1149 miles of paving, and about 4600 miles of untreated gravel roads in this system. There is a considerable mileage of bituminous treatments on the secondary system.

SURFACE TREATMENTS PROVE POPULAR

During the past six years many variations of the method of treatment for different kinds of road surfaces have been used. In this paper, however, I shall describe only the two distinct types mentioned. I believe that they most closely correspond to the designation of "blotter treatment." The elimination of dust, the conservation of material and the better all year riding surface, of course, in addition to the reduced cost of the roadway and vehicle operation, constitute the reasons for bituminous treatments. The fact that the mileage of roads so treated has so increased in Minnesota is evidence that bituminous surface treatments have been the most satisfactory improvement for certain types of roads. I shall, however, confine myself to a description of the methods used rather than to giving the reasons for bituminous surface treatments.

METHODS USED IN CONSTRUCTING GRAVEL ROADS

Before going into detail regarding the bituminous treatments, I think it advisable to describe the kind of gravel we have and our method of constructing gravel roads. Minnesota, for years, has constructed gravel roads by the so-called feather-edge method, using, as a rule, available local gravel which usually is of glacial origin. This gravel is used as it comes from the pit, except that the part retained on a 1-in. circular opening either is crushed to such a size that it will pass this sized

opening, or if, it is a small amount, it is left in the pit. Occasionally, excess fines are removed by a double-screen operation.

PER CENT TOTAL SAMPLE RETAINED N^o10

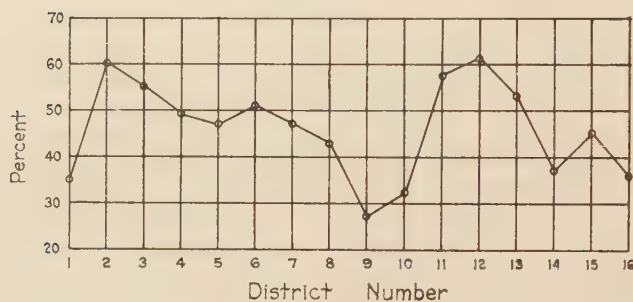


CHART No. 1

This slide shows a typical analysis of the gravel used in various sections of the state. You will note that from 28 to 60 per cent of the material is retained on a 10-mesh sieve, or in some instances gravels are used in which nearly three-quarters of the gravel put on the surface will pass a 10-mesh sieve.

PER CENT SAND RETAINED N^o60 OF PART PASSING N^o10

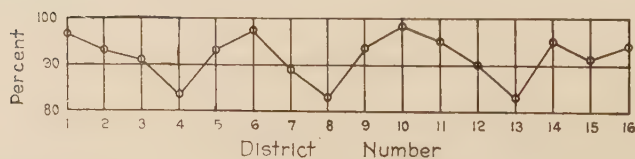
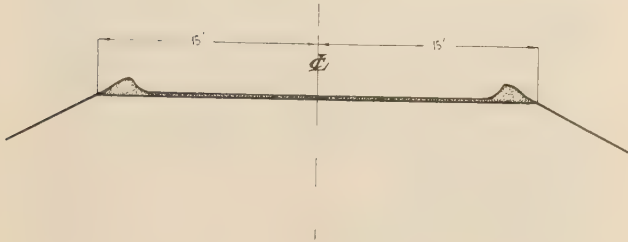


CHART No. 2

This slide shows the percentage of that portion passing a No. 10 sieve which is retained on a 60-mesh sieve. You will note that very little passes a No. 60 sieve. This is quite a different gravel than some of you are accustomed to using.

DIAGRAM No. 1

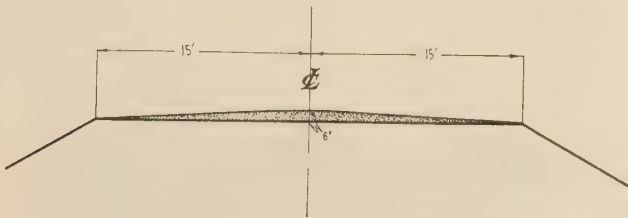


CROSS-SECTION OF GRAVEL, WINDROWED ON SHOULDERS

FEATHER-EDGE TYPE OF CONSTRUCTION

In construction by the feather-edge method, the subgrade is smooth and flat between shoulder lines which are usually about 30 to 32 feet apart. Approximately 1600 cubic yards of gravel are dumped on the road and then windrowed onto the shoulders with blades, except that about 1 in. is left on the roadway. As the center compacts the blade brings in more gravel from the windrow along the shoulders until the road cross-section is about like this.

DIAGRAM No. 2

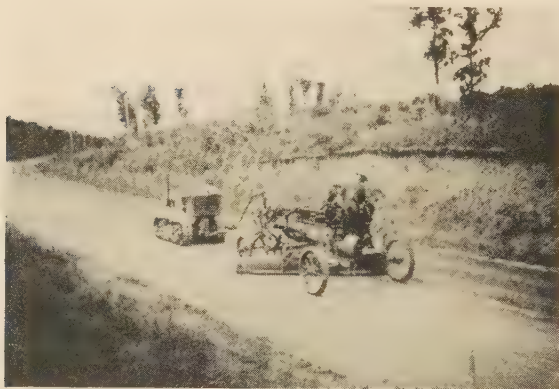


CROSS-SECTION OF GRAVELED ROAD

VALUE OF PROPER MAINTENANCE

Continuous maintenance, of course, is necessary. When roads are constructed in this manner on sandy subgrades with local gravel which is deficient in binder, we have the loose surface in dry weather which I previously mentioned.

FIRST OPERATION

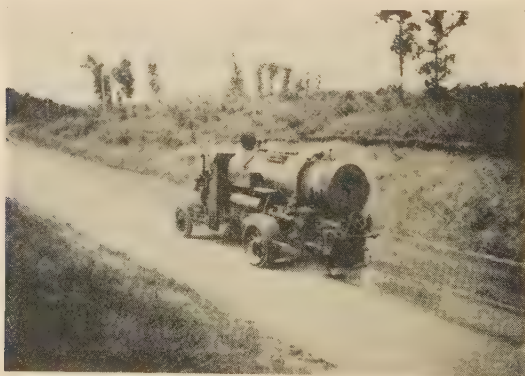


GRADING THE LOOSE GRAVEL TO CENTER OF ROAD, THUS FORMING A SMOOTH, HARD SURFACE FOR PENETRATING WITH BITUMINOUS MATERIAL

METHODS USED IN SURFACE TREATMENT

The method of treatment for such a surface is as follows: The first operation consists of grading all of the loose material to the center of the road, thus exposing a smooth, hard surface. In only a few instances have we resorted to sweeping, for, usually, the surface is such that sweeping would not be possible. The ideal road surface, at the time of the first application, should be smooth, well compacted, dry and free from dust.

SECOND OPERATION



SPRAYING FIRST COAT OF BITUMINOUS MATERIAL, ONE QUARTER TO ONE-THIRD GALLON TO THE SQUARE YARD

The second operation is the spraying of the prepared surface with about 0.3 to 0.5 gal. of heated bituminous material.

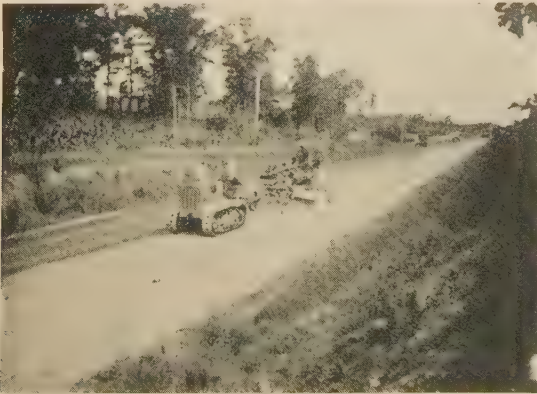
THIRD OPERATION



AFTER ABOUT TWENTY-FOUR HOURS THE FIRST COAT OF BITUMINOUS MATERIAL HAS COMPLETELY PENETRATED AND SET UP. IT IS THEN SPRAYED AGAIN WITH ONE-QUARTER TO ONE-THIRD GALLON OF BITUMINOUS MATERIAL PER SQUARE YARD AND IS AT ONCE COVERED BY GRADING THE LOOSE GRAVEL, PREVIOUSLY REMOVED, BACK INTO THE FRESH BITUMINOUS MATERIAL

Third operation. After about 24 hours, or when the first application has completely penetrated and set up, the surface is again sprayed with $\frac{1}{4}$ to $\frac{1}{3}$ gal. of bituminous material, and is covered at once by blading the loose material previously removed onto the fresh bitumen. This would be considered the "blotter coat." In case the bladed material contains an excess of fines of a nongranular nature, it is wasted over the shoulder, and suitable material for covering is windrowed on the opposite shoulder, bringing the total amount of covering material up to about 350 cu. yd. per mile. The best covering material is gravel or, where available, stone chips, all passing a $\frac{3}{8}$ or $\frac{1}{2}$ -in. screen and having from 15 to 30 per cent passing a No. 10 sieve. Where we have aggregate plants nearby, such a material is used. Usually, however, selected local deposits are used and the amount passing the No. 10 sieve may be as high as 60 per cent.

FOURTH OPERATION



THE OPPOSITE SIDE OF THE ROADWAY IS THEN CLEANED WITH THE GRADER, THROWING THE LOOSE GRAVEL INTO A WINDROW OVER THE EDGE OF THE TREATED SECTION AND LEAVING THE OPPOSITE SIDE FREE FOR TREATING

Fourth operation. The opposite side of the roadway is then cleared with a grader, throwing the loose gravel into a windrow over the edge of the treated section and leaving the opposite side free for treating.

FIFTH OPERATION



THE REMAINING SIDE IS TREATED WITH THE PENETRATION COAT WHICH IS ALLOWED TO SOAK IN AND SET UP IN THE SAME MANNER AS THE FIRST SIDE TREATED

Fifth operation. The remaining side is treated with penetration coat and allowed to set up in the same manner as the first side treated.

SIXTH OPERATION



THIS SIDE IS THEN SPRAYED WITH THE SECOND COAT OF BITUMINOUS MATERIAL AND THE WINDROW OF LOOSE GRAVEL IS GRADED INTO IT FOR COVER THE SAME AS BEFORE

Sixth operation. This side is then treated with a second coat of bituminous material and loose-graded material bladed in from side for cover the same as before.

Seventh operation. The roadway is dragged a number of times in order to smooth it and work all the gravel possible into the bituminous material. This dragging operation is continued for a period of three to

SEVENTH OPERATION



THE ROADWAY IS DRAGGED SEVERAL TIMES TO SMOOTH IT UP AND WORK ALL THE GRAVEL POSSIBLE INTO THE BITUMINOUS MATERIAL

five days, or until the surface has set up to such an extent that dragging does not do any good, or the surface is in a hard condition. At this time any small breaks or holes should be patched immediately with premixed material, using the same grade of bitumen and the same aggregate as is used for the "blotter coat." If large holes develop, a coarser grade of road metal may be used to insure a more stable patch.

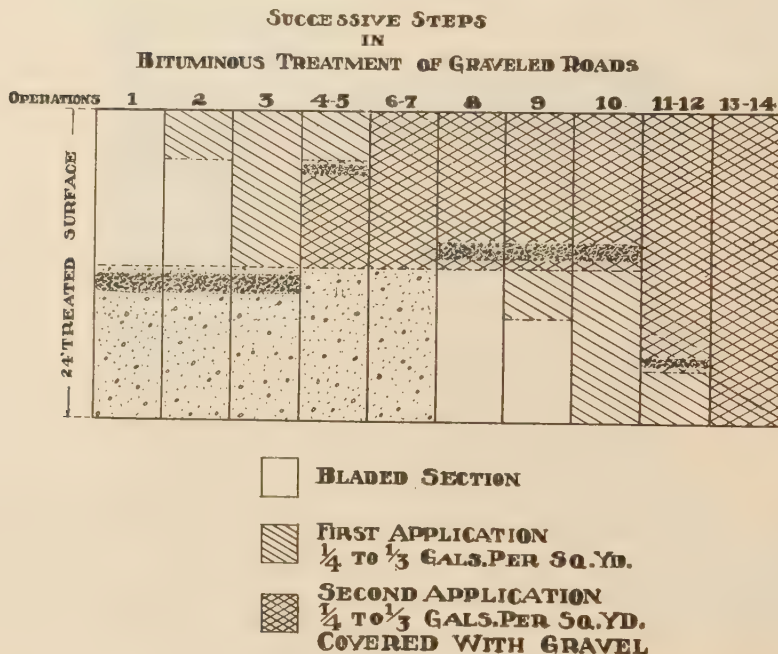
USE OF CUT-BACK ASPHALT

Diagram No. 1 shows the successive steps. At completion, the crown for a 30-ft. top would be from 6 to 9 in. This method is really a combination of the penetration and surface mixing methods. Its success depends largely on the penetration into the compacted surface. We find that this makes a good bond between the old road bed and the surface. There has been very little trouble with creeping of the surface. The thickness of the bituminous mat, after the first treatment, is about $\frac{3}{4}$ in. Subsequent treatments, scarifying, etc., increase the thickness of the mat and result in its becoming 3 or 4 in. thick. In this class of treatment in the past, tar usually has been used, but recently we have made some use of cut-back asphalt and it appears to be very promising.

DETOURS URGED IF POSSIBLE

Traffic usually is carried continuously on the road, although where it is easy to detour, this should be done. The traffic is carried on the untreated side until after the "blotter coat" is applied, after which it may be carried immediately on the treated section. Where there is considerable sand in the "blotter coat," we have little trouble with the material picking up and annoying the motorist. If the "blotter coat" is entirely of loose pebbles there may be considerable trouble. Although it may make a better road in the end, it will be very troublesome under traffic during this period. In one treatment on the north shore of Lake Superior in 1929 we used a cover coat of lake-shore gravel pebbles be-

DIAGRAM No. 1



tween $\frac{1}{4}$ and 1 in. size. Cars passing through were quite badly spattered. Such a covering did not act as a "blotter." In most of our road construction, the sand content in the "blotter coat" has been rather high. We place warning signs at the ends of the sections that are being treated to inform the motorist what to do. Occasionally we also place patrolmen at the ends to stop the motorist and tell him how to proceed. Occasionally the flagmen only permit traffic in one direction on the portion of road that is being treated so as to avoid turnouts. In a few places where traffic has been troublesome especially, we have had highway patrol officers. The traveling public should be protected. Any unwarned motorist who gets his car spattered with bitumen has a just grievance. The proper method of protecting the motorist depends on the method of treatment, the intensity of traffic and the local conditions.

COST OF THE WORK PER MILE

On this type of road the daily traffic varies between 700 and 1500 vehicles per day. Initial cost for a 24-ft. surface ranges between \$1,600 and \$1,800 per mile. One patrolman with auxiliary equipment and help can handle successfully about 20 miles of this kind of road, taking care of the patching, cutting of the grass, repairing washouts, etc. On a typical section of such bituminous treatment north of Brainerd, Minn., on Trunk Highway No. 19, a total of 17.6 miles were treated first in 1926 by the method just described. The cost of the first treatment was \$1,669

per mile. The entire cost of maintaining the surface for 1927 was \$995. This included, in addition to the usual patching, a retreatment of about $\frac{1}{4}$ gal. per sq. yd. of bituminous material, and 125 cu. yd. per mile of cover. The entire cost for 1928 was \$416, which included blading, smoothing, patching, etc., but no retreatment. In 1929 the road was retreated in a manner similar to the 1927 treatment at a total cost of \$1,044. This particular road carries more traffic than ordinarily is the case on our bituminous treatments. The traffic count August 5 to 11, 1929, was 2109 vehicles per day. The maintenance of this road is such that practically at all times it provides as good and satisfactory a riding surface as would a pavement.

ANALYSIS OF SUBGRADE MATERIAL

The initial treatment of road oil on heavy clay and gumbo subgrades was in 1925 in the northwestern part of the state. This area is very flat, being, in fact, the bed of the glacial Lake Agassiz. Gravel had to be shipped long distances and the road became slippery and greasy in a very short time after a heavy coat of gravel had been placed on it. The feather-edge method of construction previously described was used. It was found that the more fines there were in the gravel the longer time it would take for it to sink into the heavy soil underneath. A blanket coat of such material under the gravel had been the method of construction often used in that area up to the time that oil was first applied. It was not, however, in general, a satisfactory method of construction. Oil has been much more satisfactory and less costly.

On new construction the oil is placed directly on the subgrade which is about 30 to 32 ft. wide between shoulders and should be smooth and have little crown at the time the oil is applied. An idea of the nature of the subgrade in this area may be obtained from the following analysis:

Passing No. 10 sieve.....	99.5%
Total sand	8.6%
Total silt	21.8%
Total clay	69.6%

A typical analysis of the oil most generally used is as follows:

Specific gravity	1.044
Flash	164° C.
Specific viscosity at 60° C.....	12.9
100 Penetration residue.....	65.2
Ductility of residue.....	100+
Loss at 163° C.....	2.8
Total bitumen (soluble in CS ₂).....	99.91
Total bitumen insoluble in 86° Naphtha.....	16.23

Considerable care is taken to see that the subgrade at the time of treatment is well compacted, smooth, free from dust and dry. Weather conditions play a great part in the satisfactory application of oil on this class of work. Warm weather aids the penetration of the oil into the subgrade. Rainy weather tends to retard the work because it is difficult to get the surface dried out sufficiently to obtain the necessary penetration into the soil.

DIAGRAM NO. 2

SUCCESSIVE STEPS IN BITUMINOUS SUB-GRADE TREATMENT

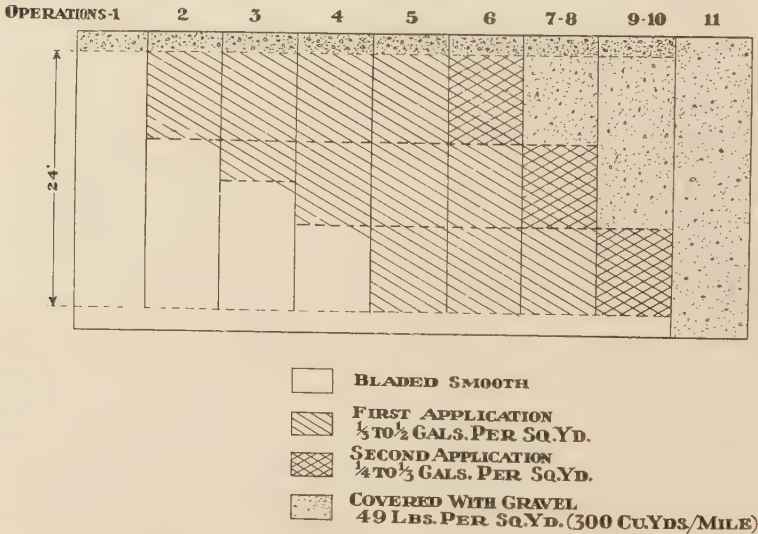


Diagram No. 2 shows in order the operations on this type of treatment. About 400 cu. yds. of cover material per mile are used. The cover material, as previously described, preferably is of the pea size, with a small percentage of sand, but usually selected local deposits are used. The gravel takes the wear. Too much emphasis cannot be placed on having the surface of the road well above the water table. The thickness of the oiled surface is about $\frac{3}{4}$ of an inch. This is not sufficient to assure the carrying of extremely heavy traffic, or the carrying of ordinary traffic, if the soil beneath this thin crust is plastic. We employ heavy grading in these sections, running 16,000 to 22,000 yds. per mile for a 30 to 32-ft. road. This brings the surface of the road from 4 to 5 ft. above the bottom of the ditch line and the ditches usually are quite wide.

BEFORE AND AFTER TREATMENT

This view taken on a road north of Ada, Minn., is typical of roads in this area. This picture was taken after heavy rains. Notice the water in the ditches.

Contrast that with this view which was taken on an adjacent untreated section. The difference is most pronounced when the frost is coming out in the spring. I do not believe our treatment of this type of road would be effective if it were not for the high grade-line which adds to the stability of the road bed.

Also there is a considerable difference in the supporting power of the different clay soils. Some so-called clay soils contain a high silt content and their supporting power when wet may be compared with quicksand, while other clays, like the familiar blue clay, will always have a good

FIG. 1



ROAD NORTH OF ADA, MINNESOTA, HAVING ONE YEAR'S
TREATMENT WITH BITUMINOUS MATERIAL

load carrying capacity. The soil in the subgrades we have treated is of the latter type. Such a soil absorbs water very slowly but is extremely sticky and disagreeable when wet. This thin bituminous crust acts as a roof over the road and sheds the surface water. It also forms a crust,

FIG. 2



ROAD SOUTH OF ADA, MINNESOTA, UNTREATED SECTION

or perhaps you might say a diaphragm, over the clay which prevents the gravel from sinking into the soil underneath. I do not believe that such a method of treatment would be at all satisfactory unless the drainage were taken care of and the subgrade is of a stable composition.

The initial cost of this type of treatment is about \$1,400 to \$1,600 per mile. The bituminous material used does not form a hard mat. It

can be cut with blades, especially during hot weather. As a result there is considerable blading in the maintenance. In patching we use a mixture of the road oil and cover gravel. On a typical section south of Ada, Minn., on Trunk Highway No. 6, 25 miles were treated first in 1926 by the method just described. The cost of the treatment was \$1,448 per mile. In 1927 the road was retreated, using more bituminous material and more cover at a cost of \$1,262 per mile. The maintenance for 1928 with no retreatment was \$615 per mile. Maintenance for 1929 with no retreatment will probably be about the same as for 1928. The traffic, during the period of August 5 to 11, 1929, was 703 vehicles per day. This road is very much better during wet periods than are adjacent untreated gravel roads.

NEED OF STUDYING BASIC PRINCIPLES

Bituminous treatments were tried in Minnesota first as experiments under the direction of an engineer employed in the laboratory. As the mileage increased, an engineer from the laboratory continued as adviser to the sixteen maintenance superintendents who are immediately in charge of the various maintenance districts into which the primary road system is divided. This engineer serves as a liaison officer between the central office and the field. It is also his duty to develop new methods. The result is that we have had very good coordination, but the routine has not allowed sufficient time for research.

In conclusion I wish to urge the necessity of further research. At present there is too much of a tendency to judge by the appearance of the bituminous surface without trying to ascertain basic principles. A method of treatment suitable in one place may be entirely unsatisfactory in another. Then, too, a large amount of money may be spent in bringing in material to build the surface in some standard manner, whereas, if we only knew how, it is entirely possible that a suitable surface might be constructed from local materials at a much less cost. Thus a much greater mileage of suitable roads would be obtained at the same cost.

EXPERIMENTS IN PENETRATION

Last winter we experimented in our laboratory on penetration of different bituminous materials into clay soils. We made up balls, about the size of golf balls, and found that by soaking them in oil a certain length of time we got a maximum penetration of about $\frac{1}{8}$ in., whereas by adding a small amount of hydrated lime to the soil, the bituminous material completely penetrated to the center. I mention this not only to indicate that there may be possible methods of improving the soil before oiling, but also to point out that the soil properties may not always be the same on different roads even though they have the same general appearance. There is a considerable difference also in the behavior of different road oils on these heavy soils.

DISCUSSION

CHAIRMAN SMITH: The paper just presented by Mr. Lang is an excellent one. I feel that so far as Canadians are concerned, they would know Mr. Lang's paper better, principally the first part of it, by what we know as "the mulch treatment." This treatment has been applied successfully by us in areas where there is fairly heavy tourist traffic but comparatively light truck traffic. The road north of Toronto is accepting traffic as high as 4000 vehicles a day during the summer months. This particular road gave excellent service until this spring. Last year we opened the road for winter traffic, keeping the snow clear throughout the winter. The consequence was that this spring, owing to the traffic, the road went to pieces. If you are not obliged to open the road for winter traffic, this method of treatment can be maintained successfully for a good many years. The paper is open for discussion and I will be glad to hear from any one interested enough to start it. I am sure Mr. Lang will be glad to answer any questions.

MR. S. R. MURRAY, MILWAUKEE, WIS.: It is said that imitation is the sincerest form of flattery. While I was with the Wisconsin Highway Commission, I made several trips to Minnesota and examined their oiled roads, but I never had the pleasure of meeting Mr. Lang. My activities were confined closely to the vicinity of the City of LaCrosse, but I want to ask Mr. Lang if Minnesota followed the practice of oiling the subgrade to conserve the amount of gravel on the newly built roads? I am told that by oiling a number of subgrades they were able to save half the gravel on the new gravel road, by reason of its not being lost in the subgrade. That looked feasible to me. Did they do that?

MR. F. C. LANG: You are entirely correct. We saved half, and in many cases, much more. This oiling formed an impervious surface crust which prevented the gravel from sinking into the soil. In the costs which I give one should not overlook the fact that if oil had not been used, considerable more gravel would have been, at a considerably increased cost.

MAJOR F. M. DAVISON, WASHINGTON, D. C.: I would like to ask Mr. Lang whether this "blotter treatment" would be applicable to city streets where the water table is quite close to the ground and most of the drainage would have to be carried in side ditches where we would not have a great deal of crown? Could we use this at all as a sort of preliminary or stabilization treatment?

MR. LANG: I would say that the first method I described in sandy earth has been very successful in towns in that area. I certainly would not advise a treatment with a heavy soil where you had high water and a fill, with no side drainage.

MR. J. S. BURCH, WASHINGTON, D. C.: I would like to ask Mr. Lang a question in regard to frost action, whether or not these clays are subject to serious detrimental frost action, and whether or not this oil treatment seems to overcome, to some extent, that difficulty?

MR. LANG: The clay road I described was in a very flat country and had a high grade-line. Our so-called frost boils usually occur on side hills or in flat country where there is a low grade-line. A frost boil is the

result of having the soil immediately under the surface crust saturated so that it is very unstable. They appear to occur only in the spring. Oiling would be of value only in preventing surface water from softening the gravel crust.

CHAIRMAN SMITH: Is there any further discussion? The next paper on this program is "Surface Treated Gravel and Macadam Roads" in Oregon, by Mr. R. H. Baldock, maintenance engineer of the Oregon State Highway Commission.

Surface Treatment of Gravel and Macadam Roads in Oregon

By R. H. Baldock, Salem, Ore.

Maintenance Engineer, Oregon State Highway Department

There has developed during recent years a national interest in the construction of low cost bitumen-bound roads. Several basic reasons are responsible for this trend. First of all, funds for pavement construction have not kept pace with the increase in traffic, and excellent gravel surfaces that carried a few hundred cars per day without distress have become rough and dusty as the vehicles multiplied. In the second place, the wear has increased so fast that the authorities responsible for the maintenance are appalled by the expense of replacing the loss in thickness. Last, but by no means least, the motor car owner and the operators of the motor stage and truck lines have been loudly complaining of the rough and dusty conditions of such highways and the inconvenience and expense resulting therefrom.



LOADING SCREENINGS FROM STOCK PILE. OREGON STATE HIGHWAY DEPARTMENT

For many years the automobile manufacturers have, by changes in design, increased the safe driving speed of the automobile. During late years this idea has spread to the manufacturers of fast pneumatic tired trucks, which are capable of carrying a 5-ton load at 40 miles per hour. All this has been made possible by the design and construction of the net work of primary and secondary highways throughout our great country. However, fast speed demands not only low gradients and easy curvature, but a smooth, hard, dustless surface which is not achieved by the use of untreated gravel or broken stone. While no authentic data is available, it is safe to assert that the annual loss to the motor car and truck owner in operating over rough and dusty gravel and macadam surfaces in the form of lost time, injury from dust, tire wear and road shock is much greater than the loss to the highway authorities in increased maintenance costs.

VALUE OF SURFACE TREATMENT

From such data as we of Oregon have compiled, we believe that the economical traffic point at which to surface treat gravel and broken stone surfaces, is approximately 300 cars per day. When properly constructed with the requisite foundation strength and adequate drainage, such roads will care for a very large number of light passenger cars. Heavy motor trucks do more damage and after a certain concentration



SPREADING STONE FROM TRUCK ON THE ROAD. OREGON
STATE HIGHWAY DEPARTMENT

of such traffic the increased maintenance costs forces a change to the more stable pavement construction.

Asphaltic oil and tar have been used for many years on the Pacific Coast for surface treatments but, in general, such early treatments were constructed without refinement in workmanship and on poorly prepared surfaces. As a rule, light viscosity oils and fine, dirty cover materials were used and rough, wavy surfaces developed. About six years ago interest in this practice sprang up in several sections of the country. Oregon began the use of oil in surface treatments in 1923. The first treatments were in the form of dust palliatives, using a light asphaltic oil known on the Pacific Coast as "fuel oil." It was soon found necessary to increase the amount of oil because the thin spread lasted but a short time. Moreover, the oil tended to cake in spots and develop pot holes. The spread of oil was increased to about 6/10 gallon per square yard, placed in two applications on a well-prepared, hard and compacted base, which was swept clean. Considerable success was attained by this method.

USE OF THE HEAVIER OILS

However, it was found necessary to reseal such surfaces each year to prevent the admission of moisture and the light oils tended to emulsify and wash out during the winter, necessitating considerable patching. The continual application of light oil each year with the inherent inconvenience to the public, together with the reasons above mentioned, caused the Oregon State Highway Department to investigate the use of heavier oils.

Heavy oil surface treatments have been very successful in our state and more than 1400 miles have been constructed. In general, the treatment consists essentially in the thorough cleaning, by sweeping, of the surface, followed by a prime coat of light oil or tar at the rate of from $\frac{1}{4}$ to $\frac{1}{3}$ gallon per square yard. As soon as the prime coat becomes dry, heavy oil is applied at the rate of $\frac{1}{4}$ to $\frac{1}{3}$ gallon per square yard, followed by a spread of clean screenings, which are well rolled. In certain cases we specify a double coat of heavy oil, using approximately $\frac{1}{4}$ gallon on each application. The first application is followed by a spread of one-inch to one-half-inch stone at the rate of .012 cubic yards per square yard, which is broomed and rolled. After the second application of heavy oil, $\frac{1}{2}$ to $\frac{1}{8}$ -inch screenings are spread at the rate of .010 cubic yard per square yard, followed by brooming and rolling. The binder used is either a 95 per cent asphaltic oil, heavy tar, or soft asphalt. Both the oil and asphalt are from the California fields. The stone is spread by a special spreader box attached to the truck and is broomed and bladed by power graders. The oil is spread by a pressure distributor at a temperature of 400 degrees F. This treatment covers one-half of the roadway at a time, permitting one-way traffic.

LIGHT PRIME COAT ELIMINATED

Our more recent broken stone roads have been built with larger rock somewhat in accord with the waterbound macadam type and we have found that when swept clean these surfaces present a mosaic appearance, studded with coarse stone. Under such conditions, we are able to dispense with the prime coat of light oil and use the double-coat surface treatment



SPREADING STONE FROM SPREADER BOX. OREGON STATE HIGHWAY DEPARTMENT

direct. The oil adheres firmly to the large exposed stones which tack the mat firmly to the surface. This method is cheaper and eliminates the inconvenience to traffic caused by the light oil prime coat. Many of our roads are located in rough, mountainous country where detours are not possible.

In addition to the surface treatments above described we, in certain cases, use the road-mix specification. By this method the road surface is scarified to a depth of from 2 to 3 inches and mixed with an oil by a blade grader. The oil contains from 60 to 70 per cent asphalt, with a viscosity Saybolt Furol of from 200 to 300 seconds at 122 degrees F. The oil is applied to the amount of approximately 0.5 gallon per square yard, per inch of depth, loose measure, and the oil and stone are mixed with motor graders. We do not find the harrow necessary. In general the best results are attained when the surface material contains stone of 1-inch maximum size and ranges from 40 to 60 per cent passing the $\frac{1}{4}$ -inch screen. In certain cases the road is not scarified but new rock is added. We also successfully road-mix heavy asphaltic oil or tar and clean stone, followed by a seal coat and fine screenings.

BITUMINOUS MACADAM CONSTRUCTION

In addition to the construction of approximately 1400 miles of surface treatment and road-mix treatment, we have constructed approximately 150 miles of bituminous macadam ranging from $1\frac{1}{4}$ inches to $4\frac{1}{2}$ inches in thickness. Some of this mileage has been constructed by road-mixing broken stone and heavy asphaltic oil or tar and others by a modification of the penetration type, laying heavy asphaltic oil or soft asphalt and rock in layers. This work is performed by machine methods,

using power graders to spread the stone. The surface is constructed one-half width at a time. We have designated this type as "multiple lift bituminous macadam." We have now adopted a method of stage construction on the heavier traffic secondary roads under which condition the drainage is improved and the foundation reinforced by a heavy base, followed by surface treatment. After the maintenance of the surface treatment becomes material, due to the relatively thin coat, a bituminous macadam is constructed. This is placed on a proved base so that foundation failure is minimized and the surface maintenance materially decreased.



GRADER SPREADING STONE OVER THE ROAD. OREGON STATE HIGHWAY DEPARTMENT

The construction of the bituminous macadam surface in Oregon differs somewhat from the general method used in the East. An outline of our method may be of interest. The rock used is a hard trap, manufactured for the most part from the Columbia River basalt. The material is crushed, graded and stock-piled one season in preparation for the construction of the bituminous macadam the following season. The average price of this material is \$1.75 per cubic yard in the stock pile.

NATURE OF ASPHALTIC OIL USED

California asphalt is used and a two and one-half inch compacted surface requires approximately 1.6 gallons per square yard, which is from 25 to 50 per cent less than the general eastern practice for an equivalent thickness. This is probably due to a difference in the asphalt. The 95 per cent asphaltic oil we use in Oregon has a minimum float viscosity of 225 seconds at 122 degrees F, and the soft asphalt a penetra-

tion of from 150 to 250 degrees Dow at 25 degrees C. No headers are used, and the edges are kept square and true to line by the expert use of the grader, supplemented by some hand trimming with shovels.

A tack coat of asphalt is used under the base rock to cement the stone to the surface on which it is being placed. This is an aid in keying and locking the stone by preventing slipping and creeping. The stone is spread by mechanical spreader boxes attached to the trucks which back over the freshly spread oil.

USE OF EMULSIFIED ASPHALT

The stone then is shaped by the long-wheel-base motor grader acting as a strike board, which saves the cost of much hand work and affords an easy riding surface. Some hand work in spotting inequalities in the surface of the stone is necessary but the major portion of the hand work is eliminated. More courses of stone and oil are used, permitting the grader to remove the irregularities in each successive lift and insuring greater compaction in rolling. The successive lifts insure a uniform penetration of the oil.



MOTOR GRADER SPREADING STONE AND CLOSE-UP OF
SPREADER BOX ATTACHED TO REAR OF TRUCK. OREGON
STATE HIGHWAY DEPARTMENT

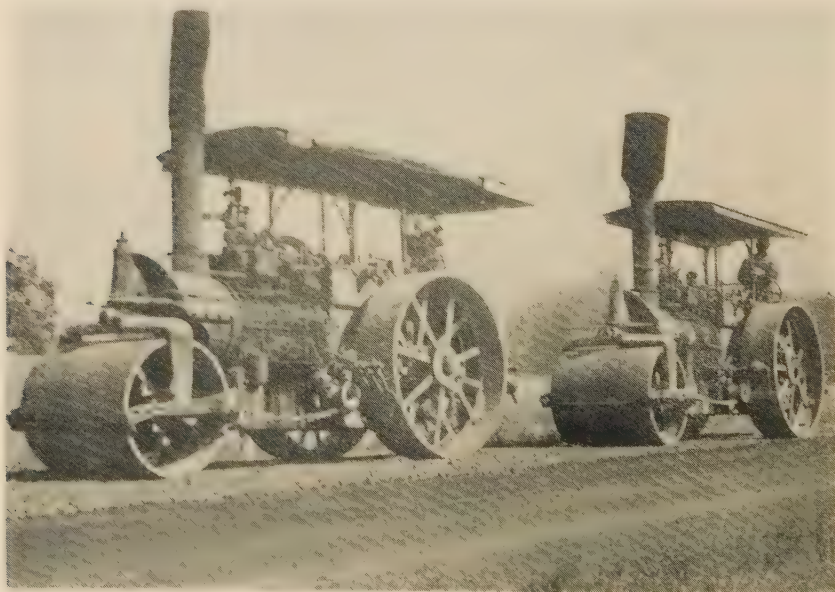
We have used about 200,000 gallons of commercial emulsified asphalt both in the surface treatment and in bituminous macadam construction, with excellent results. We have also developed a home made product by

installing a separate water tank and water spray-bar on the pressure distributor. The water was applied at air temperature with gravity pressure immediately ahead of the hot oil spray and the oil was applied under a pressure of about 20 pounds at a temperature of 400 degrees F. This made an immediate emulsion, which was momentarily quite thin and covered the stone in about the same manner as the 50 per cent water emulsified oils. The water formed steam and was driven off almost immediately so that the oil chilled and hardened rapidly. By means of this method we obtained a wonderful seal, filling all the small crevices. We were also able to use a smaller amount of oil in proportion to rock. In penetration work the stones were very well coated. Lye and soap jelly were dissolved in the water and the water was applied at the rate of 10 per cent of the amount of hot oil by volume. This home made product was used on about 50 miles of surface treatment and 5 miles of bituminous macadam construction.

NEW FOUNDATIONS AND WEARING COURSE

For the most part, the treatments began in Oregon as a dust palliative for the existing gravel and broken stone surfaces and have gradually evolved to the more expensive and more permanent treatments now in use. The success of these treatments has won the general favor of the public and the engineers are now confronted with the necessity of designing a foundation course and a bitumen bound wearing course for virtually all new projects.

We will now consider the building of new broken stone surfaces and the reinforcing of old macadams, which construction or reconstruction



ROLLING OPERATIONS FOR SURFACE TREATMENT. OREGON STATE HIGHWAY DEPARTMENT



"MULTIPLE LIFT" BITUMINOUS MACADAM CONSTRUCTION IN OREGON. CONSTRUCTED ONE-HALF WIDTH AT A TIME

is to be followed by some type of bituminous treatment. The choice of type of wearing surface should be made at the inception of the work in order to effect the greatest economy. The necessity of crushing the stone to a small size and the use of a thick mat of fine materials was quite necessary as long as the surface was maintained by graders, but this practice is no longer required, nor is it desirable where surface treatment is contemplated, inasmuch as the larger stones lock and key much better than the smaller size. It will be generally conceded that the foundation course, in all cases, should be constructed of large stone, regardless of the type of wearing course. In Oregon we are now constructing a rolled, waterbound foundation of a minimum thickness of 6 inches compacted, using broken stone of $2\frac{1}{2}$ inch maximum size. Inasmuch as the sub-grade must carry the load, an attempt is made properly to drain the sub-grade and to increase the depth of the foundation in the weaker places in order to arrive at a condition of uniform strength. In cases where surface treatment is contemplated the foundation course is covered with a 2-inch compacted layer of $1\frac{1}{2}$ -inch stone and a 1-inch compacted layer of $\frac{3}{4}$ -inch stone to afford a smooth surface. With regard to a road-mixed treatment, it is necessary to cover the foundation course with a layer of $\frac{3}{4}$ -inch-minus material to a depth of approximately 3 inches in compacted thickness. In this case 50 per cent of the top material should pass a $\frac{1}{4}$ -inch screen and about 8 per cent the 200-mesh screen. In general, it is more economical to use the road-mix type where fine gravel is easily available.

When the gravel or rock is well bound and compacted, the surface treatment type is cheaper and very satisfactory. As a rule, roads constructed of broken stone are better compacted, locked, keyed and bound

than those surfaces built of crushed gravel. In general, we have found that the surface treated roads are more stable than the light oil road-mix type, by reason of the strong mechanical lock of the compacted macadam, which opposes ridging, pushing and other surface movements resulting from traffic much better than the light oil road-mixes which have virtually no mechanical lock. We also found that the heavy oil of the surface treatment resisted the emulsification from rainfall better than the light oil used in the road-mix.



TWENTY HP. BOILER AND HEATER USED BY OREGON STATE HIGHWAY DEPARTMENT. HEATER CONTAINS 120 FEET OF TWO-INCH PIPE THROUGH WHICH OIL IS PUMPED AND HEATED BY HOT GASES. CAN HEAT TO 600° F. IF NECESSARY. MAXIMUM HEAT GIVEN, HOWEVER, WAS 425° TO 450° F.

COST OF VARIOUS TYPES OF TREATMENTS

With reference to the relative construction costs of these various types and in order to establish comparable conditions, let us assume the construction of a macadam, built of broken stone, consisting of a total thickness of 9 inches compacted, including both the base and wearing course. We will consider four types in the following order:

First, a surface treatment consisting of a prime coat of $\frac{1}{3}$ gallon of light oil or tar, followed by a seal coat of $\frac{1}{3}$ gallon of heavy asphaltic oil and screenings. The thickness of the base will be 8 inches and of the wearing course 1 inch.

Second, a surface treatment consisting of a prime coat of $\frac{1}{3}$ gallon of light oil or tar, followed by two coats of heavy oil at the rate of $\frac{1}{4}$ gallon each. Screenings will be placed on each coat of heavy oil. The thickness of the base will be $7\frac{3}{4}$ inches and of the wearing course $1\frac{1}{4}$ inches.

Third, the construction of a road-mixed type consisting of a $6\frac{1}{2}$ -inch base course and a $2\frac{1}{2}$ -inch wearing course of light oil and fine stone.

Fourth, the construction of a bituminous macadam $2\frac{1}{2}$ inches in thickness on a $6\frac{1}{2}$ -inch base course. In this case large broken stones and 95 per cent oil will be used in the wearing course. In all cases compacted thickness will be considered, based on a compaction of 25 per cent.



REOILING PASS IN CASCADE MOUNTAINS NEAR THE DALLES AT HOOD RIVER MEADOWS, OREGON. SNOW REMOVAL THREE DAYS IN ADVANCE. THE SMOKE IS FROM THE HOT OIL

COSTS IN THE STATE OF OREGON

The relative cost of constructing the various types above outlined, which in all cases contemplate a total thickness of 12 inches loose or 9 inches compacted, based on the use of broken stone and on average contract prices in the state of Oregon, are as follows:

Type	Cost per sq. yd.
(1) Surface treatment, light oil prime coat and one coat heavy oil	\$0.90
(2) Surface treatment, light oil prime coat and two coats heavy oil	0.94
(3) Light oil road-mixed type.....	1.00
(4) Multiple lift bituminous macadam type.....	1.18



CLOSE-UP OF 95 PER CENT SURFACE. ROAD CONSTRUCTED BY OREGON STATE HIGHWAY DEPARTMENT

These costs include the construction of both the base and wearing course, and also include the cost of the engineering and inspection. On the assumption that the base rock is in place, the costs, per square yard, of the wearing course only, in the above types, would be 11, 15, 35 and 53 cents, respectively.

A comparison of the relative costs of the maintenance of the broken stone and gravel before and after treatment, based on six years of experience, disclosed that we had saved approximately 13 per cent of the yearly maintenance costs based on the routine surface maintenance, cost of oiling and reoilng and the wear on the untreated surfaces. On certain projects the saving was as high as 40 per cent. The cost of the maintenance of the treated surfaces was high, in general, due to drainage conditions and base failures which are now being corrected.

ROUGH SURFACE TREATMENT FOR BLACK PAVEMENT

Where the drainage is good and the foundations are adequate we have found the cost of the maintenance of the surface treated type to be from three to four hundred dollars per mile per year, based on a retreatment every three years. We have only slight data on the maintenance cost of the newly constructed bituminous macadam at the present time but this should be quite nominal.

The traffic on our oiled macadam surfaces varies from 200 to 2500 motor vehicles per day. No apparent damage is caused by the concentration of light passenger car traffic. The maintenance costs seem to be in proportion to the number of heavy trucks. Many of our secondary roads carry, at times, a concentrated log hauling traffic. These roads

constitute a problem in that the traffic is quite nominal, other than that caused by this one industry. This abnormal traffic, in general, does not continue for a very long period on any one road.

It may be of interest to mention in passing, the non-skid treatments of asphaltic concrete pavements. We have over 600 miles of this type of surface in Oregon, a large portion of which is located in the western part of the state where the rainfall is very heavy. These surfaces become quite slippery when wet or frosty, and we began three years ago to experiment with non-skid treatments, culminating in the development of a very successful practice. The procedure consists essentially in the use of heavy oils or tars, and screenings, approximately along the same lines as described under the surface treatment of macadam, except that less oil and coarser stone are used. The cost is approximately 10 cents per square yard.

OILED ROADS HAVE DEFINITE PLACE

Oiled roads have a definite place in our state highway system and will provide smooth, dustless surfaces in sections that never can afford pavement. Bituminous macadam is a still higher intermediate type between gravel roads and the more expensive pavement surfaces and under certain conditions of traffic gives a smooth riding, non-skid surface at a nominal cost. I think most of us expect too much of these low cost treatments and tend to minimize the probable maintenance costs. While the low cost oiled roads give excellent service with moderate traffic, they should not be confused with pavements. The employment of machine methods in building bituminous macadam surfacing is, I believe, of considerable importance in obtaining a smooth surface at a low cost.

The use of emulsified asphalts is, in general, governed by the price.



SURFACE TREATED ROAD IN OREGON



SURFACE TREATED ROAD IN OREGON. THIS SECTION, OILED IN 1923, IS STILL IN EXCELLENT CONDITION

since freight on water is quite an item. However, from our experience the home made variety is deserving of considerable study and research. From our experience, the most important consideration in the construction of these low cost bitumen treated roads is the presence of well-drained bases, stable subgrades and adequate foundations, from which good results can be obtained with most any of the various methods of treatment, provided that proper attention is given to the details of construction.

I might mention that following our first surface treatments with light oils and tars, the public was so pleased with the elimination of the dust that there was no serious complaint made, but as this program continued considerable inconvenience developed, due to oil splashing on the cars. When one thousand cars per day needed washing, at five to ten dollars per car, the resultant expense to be assumed by the public became quite large.

As a result of the complaints a change in practice was made which entirely eliminated that evil. This consisted of the elimination of the light oil prime coat and the use of a heavy asphaltic oil direct, applied to one-half of the roadway at a time, and followed by screenings in each case, which prevented the tires from coming in contact with the fresh oil at any stage of the operation.

The oldest section we have treated with heavy asphaltic oil has now gone four years without retreatment. It may be possible for sections to hold five years or more without further treatment.

DISCUSSION

CHAIRMAN SMITH: I notice that, in his paper, Mr. Baldock made a

statement as to the cost of surface on a square-yard basis. In Ontario we have discontinued paying for paving on the square-yard basis. We pay by the ton. There was a time when it invariably happened that an honest contractor had a particularly zealous superintendent who insisted on making the surfaces possibly a quarter of an inch thin, and a quarter of an inch per mile, roughly, meant about two thousand dollars on a contract eight or ten miles in length. Thus a very fair profit would be made on the job. We have now arranged with the contractor—and, as a matter of fact, he is very well satisfied with the arrangement—to pay everything on a tonnage basis. This paper is of great interest. I know that every state has a macadam road requiring attention, and I am sure that the paper presented deserves especial consideration and discussion. Anyone who has anything to say in connection with the discussion will be heard with pleasure, and I am sure Mr. Baldock will be glad to answer any questions.

MR. R. H. BALDOCK: In answer to the chairman's remarks, with reference to the costs based on a square-yard basis, I will advise that our



SURFACE TREATED ROAD CONSTRUCTED BY OREGON STATE HIGHWAY DEPARTMENT

payments to the contractor are based on cubic yards, or tons, with relation to the aggregate and on the gallon measure in the case of the bituminous binder. I merely reduced the costs to a square-yard basis in order to avoid complicated computation in reaching a comparison of the costs of the various types.

CHAIRMAN SMITH: Our time is passing, gentlemen. We have three more papers yet before lunch. If there is no further discussion of this paper, then we will go on to the next, which is "Treatment of Highway Subgrades With Asphaltic Oils," by Mr. C. A. Hogentogler, senior highway engineer of the U. S. Bureau of Public Roads.

Treatment of Highway Subgrades with Bituminous Materials

By C. A. Hogentogler, Washington, D. C.

Senior Highway Engineer, U. S. Bureau of Public Roads

and

Henry Aaron, Washington, D. C.

Junior Highway Engineer, U. S. Bureau of Public Roads

In order thoroughly to comprehend the discussion to follow, one has only to remember that, during either increase or decrease of the volume of the soil mass due to change in moisture content or to change in degree of consolidation, only the void volume or pore space changes, the volume of the soil particles remaining constant.

Either bituminous or other types of treatment may prove beneficial if they serve to increase the stability of subgrades. And stability or the resistance furnished by subgrade soils to flowing laterally depends upon the two mechanical properties:

(a) Internal friction or that portion of the resistance to shear which is dependent upon the external force applied, and

(b) Cohesion or that portion of the resistance to shear which is independent of the external force applied.

The significance of the term "internal friction" is illustrated by the performance of two pieces of sandpaper when pressed together. Under these conditions they exert no resistance to being pulled apart. They exert resistance to sliding over each other, however, dependent upon the pressure with which they are pressed against each other.

The significance of the term "cohesion" is illustrated by the performance of two pieces of flypaper when pressed together. Under these conditions they exert high resistance to being pulled apart, due to stickiness, or cohesion, possessed by glue-like materials brought in contact with each other. The resistance which the pieces of flypaper exert to resist sliding over each other is furnished by surface stickiness instead of surface roughness as was furnished by the sandpaper.

When a soil flows laterally, whether it pushes out from beneath a pavement edge or up into the interstices of a macadam, sliding occurs along either one plane or more planes existing in the soil. Furthermore, this sliding occurs only because the force which produces sliding exceeds the shear resistance existing in the soil along the sliding plane or planes.

INFLUENCE OF FRICTION AND COHESION

Assume, for instance, that the line CD (Figure 1) represents any plane in the soil upon which a unit soil weight (w) is acting. A unit shear resistance (t) acting along the plane CD holds the soil weight (w) in equilibrium and prevents it from sliding.

The shear resistance (t) is composed of two parts: that furnished by the resistance of the soil grains to sliding over each other (sandpaper effect) and that furnished by the cohesion (flypaper effect) existing between the soil particles. The resistance to sliding is dependent upon the angle of internal friction θ : that angle whose tangent equals the

frictional resistance divided by the pressure normal to the sliding plane. The cohesion existing between soil particles is designated as cohesion in pounds per square feet, kg. per sq. cm., etc., existing between the soil particles.

When—

θ = angle of internal friction.

N = component of w , normal to CD .

t = $N \tan \theta + C$.

On this basis the Bureau of Public Roads in its publication *Public Roads*, Vol. 10, No. 3, May, 1929, (1)¹ suggested a formula by means of which some conception could be obtained with respect to the influence exerted by both internal friction and cohesion upon stability.

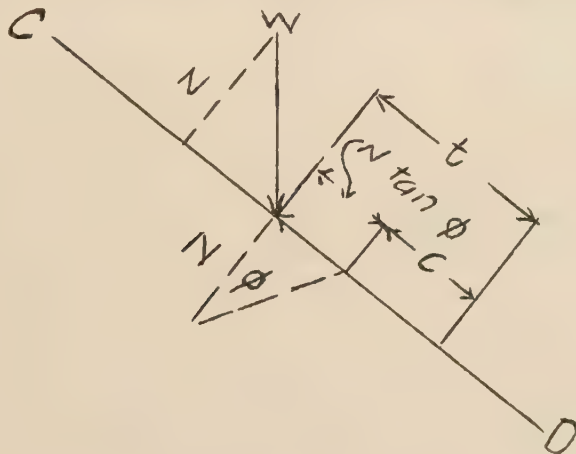


FIG. 1

According to Table 1, the stability of clays may be increased enormously by reducing their moisture contents. Furthermore the stability of wet clays may be very appreciably increased by mixing sand with them and the stability of sands may be very greatly increased by mixing clay with them.

The supporting value of sand, for instance, possessing no cohesion and internal friction in amount represented by $\theta = 34^\circ$, is 768 pounds per square foot. The supporting value of soft clay possessing cohesion in amount equal to 400 pounds per square foot and internal friction in amount represented by $\theta = 4^\circ$, equals 1857 pounds per square foot. These two materials properly combined, however, are apt to furnish support exceeding in amount 6000 pounds.

RELATION BETWEEN STABILITY AND INTERNAL FRICTION

By use of the formula referred to above it can be demonstrated also that with equal cohesion furnished by the clay the stability of the subgrade increases with increase of internal friction furnished by the sand and for equal internal friction furnished by the sand the stability of the

Table 1.—Values of c and θ for different soils and their influence upon the supporting value, q for several assumed conditions ($b = 0.71$ foot and $s = 100$ pounds per square foot).

Soil	Cohesion, c , pounds per square foot	Angle of internal friction, θ	Supporting value, ¹ q , pounds per square foot
		Degrees	
Clay, almost liquid.....	100	0	400
Clay, very soft.....	200	2	864
Clay, soft	400	4	1,857
Clay, fairly stiff.....	1,000	6	4,982
Clay, stiff	1,500	8	8,050
Clay, very stiff.....	2,000	12	12,528
Silts, wet ³	0	10	43
Sands, dry	0	34	768
Sand, predominating with some clay	400	30	6,035
Sand - gravel mixtures, cemented ⁴	1,000	34	17,838

¹ Numbers in parenthesis () refer to reports listed in the attached bibliography.

² The values of q serve for demonstration purposes only and should not be used as a basis of pavement design.

³ In silty soils, the angle of internal friction may vary between 10 and 30 degrees but the cohesion may be almost 0.

⁴ In properly graded soils (Class 1), depending upon the extent of their compaction, the angle of internal friction may exceed 34° and the cohesion may be considerably less than 1,000.

subgrade increases with increase of cohesion furnished by the clay.

Thus, for instance, when the cohesion equals 400 pounds per square foot the supporting value of the subgrade will equal either 2554 or 7596 pounds per square foot, depending on whether the angle of internal friction equals 12° or 34°. And when the angle of internal friction equals 34° the supporting value of the subgrade will equal either 4182 or 17,838 pounds per square foot, depending on whether the cohesion equals 200 to 1000 pounds per square foot.

According to available information sands possess a relatively high degree of internal friction. The greater the degree of angularity, sharpness or roughness possessed by the sand grains, the greater is apt to be the degree of internal friction furnished by the sand. Silts possess internal friction in amounts varying between $\theta = 10^\circ$ and $\theta = 30^\circ$, depending upon the moisture content of the soil. Silts possess practically no cohesion. Clay and colloids furnish cohesion but possess internal friction in relatively small degree.

Practically this information suggests that:

(1) Admixtures which serve to prevent the soil from taking up moisture serve to prevent the soil from losing cohesion and therefore should serve to increase the stability of clays when used either as binders or subgrades.

(2) Admixtures possessing cohesion should serve to furnish cohesion additional to that possessed by the soil. Admixtures of this type therefore should serve to increase (a) the stability of cohesionless silts when used either as binders or subgrades and (b) the stability of sands when used as subgrades.

(3) Admixtures of granular materials possessing high resistance to sliding are apt to furnish stability in much greater amount than admixtures of granular materials possessing relatively small resistances to sliding.

Soils may become wet due to water furnished by seepage, capillarity or frost action. Water furnished by seepage must be intercepted and removed by artificial drainage.

CAPILLARITY DUE TO SURFACE TENSION OF WATER

The capillary pressure which forces water up through the soil pores is the same force surface tension which drives water up into a capillary tube. When the surface tension equals 75 dynes per cm. (water temperature slightly above 0° C.) and when r equals the radius of the capillary tube in cm. the maximum theoretical capillary rise h in cm. equals $\frac{0.1531}{r}$ (2).

Accordingly the height of capillary rise would be expected to increase as the soil particle diameter decreases. Thus in a tube 0.01 cm. in diameter water would be expected to rise to a height of $\frac{0.1531}{0.005} = 30.6$ cm. and in a tube 0.001 cm. in diameter water would be expected to rise to a height of 306 cm.

As a matter of fact the maximum theoretical height of capillary rise indicates the pressure which tends to force water into the soil, and while this force increases as the size of the soil particles decreases, the total frictional resistance exerted by the walls of the capillaries to prevent capillary rise increases as the particle size decreases.

Silts are apt to possess this proper combination of forces productive of important capillary rise. Dense clays, in contrast, when the ground water elevation is low, are not apt to suffer detrimental capillary rise. Furthermore, laboratory experiments have demonstrated that (a) the capillary rise in soils when wet may equal as much as five times the height of the capillary rise in the same soils when dry, (3) and (b) capillary moisture cannot enter soil pores containing either air or water until after the contained air or water has been driven out (4).

Practically, these facts suggest:

(1) Admixtures of materials which serve to reduce the size of the soil pores should be effective for reducing the effective height of capillary rise in silts.

(2) When the top soil is fairly dry to some distance below the ground surface, water sprinkled on the subgrade is apt (a) to enlarge the pores of the top soil and (b) to penetrate into the under soil. Consequently bituminous material applied after the water has soaked into the soil, is apt to penetrate more readily and to a greater depth than when applied on the thoroughly dry soil. Wetting the soil in this case is similar in principle to wetting a blotter prior to attempting to absorb a drop of ink.

(3) Admixtures such as hydrated lime for instance (as suggested by Mr. Lang) (5) which serve to enlarge the pore size in soils is apt to increase the depth of soil penetrated by bituminous materials. These admixtures may be of two types: (a) admixtures such as calcium which flocculate the soil due to electrolytic action, and (b) admixtures such as diatoms which, possessing porosity in high degree, mechanically enlarge the soil pores.

(4) An impervious covering applied on the surface of the subgrade when the ground water elevation is low should serve to retard the rate of the escape of air entrapped in the soil and consequently should serve at the same time to reduce to some extent the rise of capillary moisture into the subgrade soil.

RELATION OF EXPANSION TO CAPILLARY PROPERTIES AND COHESION

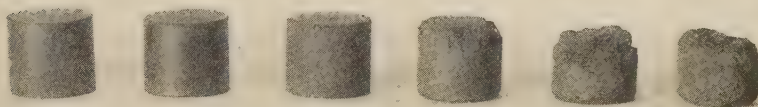
In order that soils may expand and soften, due to capillarity, water must enter the soil pores and push the soil grains apart. While the capillary moisture entering the soil attempts to push the soil grains apart, the cohesion existing between the soil particles attempts to prevent them from being separated. Consequently when the cohesion possessed by the soil either equals or exceeds the force exerted by capillary pressure to push the soil grains apart, the soil cannot expand, water cannot enter the soil and as a result the degree of cohesion possessed by the soil is not reduced in appreciable amount.

Wet compressed soils are apt to expand in less degree than the same soils when dry and soils containing both clay and colloids of the glue type are apt to expand and soften in less degree than soils which do not contain these constituents. Thus water, due to capillary pressure, is apt to enter cohesionless silts rapidly and push the silt grains apart to such an extent that the soil quickly disintegrates. Irrespective of the fact that water is apt to flow faster through wet, than through dry silts, water is apt to cause wet compressed silts to expand at a slower rate than thoroughly dry silts. Therefore, wet compressed silts are not apt to suffer disintegration as quickly as the dry silts. Plastic soils (those possessing cohesion) when dry, may or may not absorb moisture in amount sufficient to cause disintegration depending upon the amount of gluey colloid contained in the soil. Wet compressed plastic soils are not apt to disintegrate due to water absorption unless they are manipulated.

Each of 90 soil cakes, for instance, were compressed in the wet state in the subgrade laboratory of the U. S. Bureau of Public Roads, under a load equal to 3 kg. per square cm. The load was then reduced to .028 kg. per cm. and the cakes were permitted to absorb water. Subsequently

two disks, one square inch in area each, were cut from each of the 90 soil cakes. One of these disks in the wet state was immersed in water and its counterpart was first allowed to dry to constant weight in the air and was then immersed in water.

Eight of the 90 disks, containing clay less than 12 per cent immersed in wet state, disintegrated after being immersed for periods averaging 73 days. Of the eight corresponding disks immersed in the dry state, six disintegrated after being immersed for an average period of seven minutes and the remaining two swelled and cracked in appreciable amount but did not completely disintegrate after being immersed for a period of 25 days. Sixty-eight of the 90 disks, containing, with several exceptions, clay 13 to 77 per cent immersed in the wet state, have not suffered disintegration after being immersed for an average period of nine months. Of the corresponding 68 disks immersed in the dry state, 26 disintegrated after being immersed for an average period of 10 minutes, 41 disintegrated after being immersed for an average period of one hour, and with few exceptions the remaining disks cracked and swelled in appreciable amount after being immersed for an average period of 10 days.



SUBGRADE WATERPROOFING STUDIES BY U. S. BUREAU OF PUBLIC ROADS
SOIL SAMPLE BRIQUETS SHOWING DISINTEGRATION UNDER TESTS WITH WATERPROOF-
ING MATERIALS

FIG. 2

As additional evidence that cohesion in soils is apt to prevent both their expansion and disintegration due to water absorption reference is made to Figure 1. The soil cakes shown here represent soil existing at different depths in a subgrade located at Arlington, Va., treated with water gas tar in 1923. These cakes were compressed in a semi-dry state, dried to constant weight in the air and immersed in water for a period of two weeks. The two cakes shown on the left of Figure 2 contain tar in appreciable amount and exhibit no signs of disintegration. The third cake from the left contains but a small amount of tar and has suffered crumbling in slight degree along the top edges. The fourth cake from the left contains but a slight trace of tar and shows crumbling in appreciable amount near the top. The two cakes on the right contain no visible trace of tar and have suffered crumbling in advanced degree. Of ten concrete slabs constructed at Arlington in 1923 in connection with the drainage experiments, all, according to Dr. E. C. E. Lord, check-cracked except the one laid on the tar-treated subgrade referred to above.

Practically, this information suggests:

- (1) Admixtures possessing cohesion are essential to prevent silts

from losing stability due to water absorption.

(2) Clay soils, when compressed in the wet state, are not apt to lose stability due to water absorption unless manipulated.

(3) Neither clays nor silts, when treated with materials possessing cohesion in high degree, are apt to lose stability due to water absorption when either wet or dry.

FROST HEAVE DETRIMENTAL IN PERMEABLE SILTS

Frost heave which is due to the formation of well defined ice layers (6) instead of simply the expansion of water when freezing is due to three physical phenomena:

(a) The ability of water particles contained in soil pores larger than about capillary dimension to freeze at either normal freezing or slightly less than normal freezing temperatures (-1° to 4° C.), (7).

(b) The ability of water particles contained in soil pores of capillary dimension to resist freezing at abnormally low temperatures (as low as -70° C.), (7, 8 and 9).

(c) The ability of water particles of freezable size, during the process of freezing to draw to themselves from adjacent fine capillaries the small particles of water which individually do not freeze at ordinary freezing temperatures (7, 8 and 9). When drawn to the existing ice crystal, however, these small water particles freeze and increase the size of the original ice crystal. Continuation of this process causes the original ice crystals to increase in size as long as they are being furnished small water particles drawn up through the fine capillaries from the ground water supply.

In sands no important frost heave occurs (6) because practically all of the contained water freezes at normal freezing temperatures (9) and small unfrozen water particles do not exist in amount sufficient to cause the frozen particles to suffer appreciable growth.

CAPILLARY ATTRACTION IN PERMEABLE SILTS

Permeable silts which are capable of raising water rapidly and through distances of considerable amount, are apt to suffer very important frost heave. These silts may be capable of raising by capillarity at the rate of approximately 0.9 pound of water per square foot of soil per day when the ground water elevation is four feet below the surface of the ground (4). At this rate a layer of water approximately $5\frac{1}{2}$ feet in depth would be raised during one year. In fact, an average corn crop in the middle west, for an average yield, may require capillary water to be supplied at approximately this rate.

The capillary rise may be as high in cohesive clays as in silts. The speed with which water rises in clays, however, is much less than in silts. Consequently, in dense clay soils with low ground water level and absence of lateral seepage, only limited amounts of water are available for ice segregation. Under these conditions the soil adjacent to the growing ice crystals is apt to dry out and shrink, due to the loss of moisture (10). The ground water elevation in clays, therefore, must

be comparatively high in order that important frost heave may occur. Or the clay must be wet, due to water absorption, with manipulation on top of the subgrade.

Additive to the detrimental effects of heaving is the softening of the subgrade during thaws, due to the liberation of excessive amounts of water trapped by both frozen under-soil and frozen shoulders.

Due to a variety of causes frost depth under roadways is apt to be greater than under shoulders. Also thawing is apt to occur first under the roadway. Therefore, water liberated in this manner cannot penetrate the frozen soil along the edge of the roadway and reach the drain located there. Thus the drains must be placed at the location of maximum frost depth which is apt to coincide with the location of initial thawing. In this respect the center drain, according to L. L. Allen, Minnesota State Highway Department, serves (a) to lower the moisture content of the soil before freezing and (b) to provide for the disposal of water liberated by thaws. Also according to both A. C. White (11) and J. T. Henton (12), drains backfilled with gravel and placed longitudinally under the center of gravel road surfaces are effective for curing frost boils in both Minnesota and Wisconsin.

APPLICATION OF SUBGRADE STABILIZATION THEORY

Especially important with respect to frost heave (according to W. I. Watkins, U. S. Bureau of Chemistry and Soils; E. A. Willis, U. S. Bureau of Public Roads, and John Morton, New Hampshire State Highway Department), are soils consisting of sand to a depth of as much as 12 or 18 inches, underlain with silt zones which sag and permit water to accumulate:

Practically, this information suggests that:

(1) Any admixture which serves to reduce the moisture content possessed by the subgrade soil is apt to reduce the extent of frost heave.

(2) Any treatment which serves to prevent water entering the subgrade from above may serve at the same time to prevent increase in the moisture content of the subgrade to depths depending upon the permeability of the subgrade soil. Consequently a treatment of this character may serve to reduce the extent of frost heave suffered by the subgrade due to water absorption from above.

(3) Any admixture which serves to furnish cohesion in silts is apt to reduce also the extent of frost heave suffered by subgrades consisting of silt.

(4) Drains backfilled with porous material placed longitudinally under the center of gravel road surfaces, and in depth, slightly greater than the depth of frost penetration should serve to (a) reduce the extent of frost heave in silts by reducing the moisture content possessed by the soil before freezing and (b) prevent loss of stability in silts by disposing of water liberated during thaws.

According to the foregoing discussion, therefore, bituminous or other types of subgrade treatment should prove beneficial provided they serve:

(1) To reduce the moisture affinity possessed by soils.

(2) To furnish cohesion in soils.

(3) To provide an impermeable coating which prevents both water resting on top of the subgrade from penetrating the top layer of the subgrade and the escape of air through the top of the subgrade, whereby capillary moisture is permitted to enter the subgrade from beneath.

That bituminous materials possess cohesion is admitted, and, as a consequence, they must, of necessity, furnish cohesion in soils, and, as a result, serve to reduce the moisture capacity in that portion of the soil penetrated by the bituminous material. Furthermore, it must be admitted that bituminous materials may serve to furnish an impermeable coating on subgrades, provided either the layer of bituminous material or the layer of penetrated soil be thick enough. Consequently one must investigate the thickness required to furnish the particular benefit desired.

In this case, granular material, sands, slag, gravel, crushed stone, etc., applied in layers varying in thickness (1 to 4 in.) is maintained under traffic. New material is added to fill up road surface depressions when they occur.

SUBGRADE TREATMENTS AND STAGE CONSTRUCTION

According to H. J. Kirk, formerly director of the Ohio Department of Highways, a total thickness of granular material equal to 8 in. (applied in two layers, each 4 in. thick), when compacted by traffic, furnished in the resulting road surface a stability greatly exceeding that furnished by an equal thickness of mineral aggregate applied or compacted in any other way (1).

During the compaction of this granular material the soil which originally composed the top layer of the subgrade became the binder which furnished the cohesion necessary for stabilizing the resulting road surface. Consequently the thickness of soil to be treated in this case equals the thickness of soil which becomes the binder of the traffic bound surface. If it may be assumed that the layer of stone 8 in. thick originally, compacts to a layer 6 in. thick when stabilized; and furthermore, if the compacted layer may be assumed to possess a porosity equal to 25 per cent, the thickness of top subgrade soil which becomes binder, equals about $1\frac{1}{2}$ in.

If, perchance, a thickness of consolidated stone equal to 4 in. proves adequate when the soil is treated the depth of treated soil should equal about 1 in. If, for sake of demonstration, it may be assumed that an admixture equal to 5 per cent will serve to furnish reduced water affinity in clays or increased cohesion in silts in required amounts, $\frac{1}{2}$ gal. of admixture per sq. yd. will be required, provided the soil dust weighs 100 lbs. per cu. ft., and the admixture weighs 8 lbs. per gal. The binder in this case must, of necessity, be one which penetrates the soil.

But, according to previous discussion, the thickness of road surface containing a treated binder, to render equal service, would, of necessity, be less than that required by a road surface in which the binder is not treated. How much less in thickness the traffic bound road should be, when the binder is treated than when it is not, we do not at present

know. We do know, however, that increasing the degree of the surface roughness or the angularity possessed by the granular fragments serves to reduce the thickness of required road surface in appreciable amount. According to Raymond Smith of the Ohio Highway Department, for instance, the reduction in the total thickness of granular materials required to effect stabilization may be very considerable in a period of several years due to difference in both the roughness and the angularity (internal friction) possessed by the individual granular fragments. Therefore, it is possible (according to theory) that the increased minimum cohesion furnished by treating a binder may serve also to very appreciably reduce the required thickness of the road surface.

The resulting traffic bound road in this case, when surface treated, becomes:

- (1) A road surface which has been thoroughly tested by traffic for the existence of weak areas.

- (2) A highly compacted combination of mineral particles bound together by a treated material from top to bottom.

- (3) A waterproof, impervious covering which should serve to prevent water penetrating the subsoil from above and capillary moisture entering into impervious soil from below.

When these treatments, on silts not subjected to frost action, and on clays, are supplemented by drainage to intercept seepage; and when these treatments on silts subjected to frost action are supplemented by drainage both to intercept seepage and reduce the extent of the detrimental effects of frost heave, the maximum support, to be furnished by a stable, impervious wearing course, bonded homogeneously into a subgrade protected as much as possible from softening, is obtained.

SUBGRADE TREATMENTS AND MACADAM PAVEMENTS

Primarily, the failure of macadams on other than elastic subgrades is due to the subgrade soil penetrating the interstices of the macadams. In order that this may occur, (a) the subgrade soil must be wet and (b), voids in appreciable amount must exist in the under-course of the macadam. Applying bituminous material on the subgrade and covering with a cushion of granular material before constructing the macadam, supplemented by drainage as specified for stage construction, is suggested to prevent failure of this character.

Sands are not apt to work up into the interstices of macadams. The object of treating them in this case, therefore, is to furnish the cohesion necessary for stabilizing cohesionless materials. The increased stability furnished by treatments of bituminous materials which penetrate the sands to a depth equal to $1\frac{1}{2}$ to 2 in. may serve to permit a reduction of appreciable amount to be made in the thickness of the macadam wearing course.

The object of the treatment on clays is to furnish impermeable top coating. Therefore, in this case, the depth of soil penetrated should be such as to furnish adequate bond between the bituminous coating and the dense subgrade soil. It is possible that bituminous materials which penetrate the subgrade soil to a depth of $\frac{5}{16}$ to $\frac{3}{8}$ of an inch will furnish the bond in required amount.

The procedure is as follows: On the thoroughly consolidated subgrade apply the bituminous material, and cover with a blotting layer of granular material. The proper amount of bituminous material to be applied is not definitely known, but probably varies between $\frac{3}{8}$ and $\frac{3}{4}$ of a gallon per square yard. Apply blotting material at the rate of about 100 cu. yd. per mile for a treated roadway width equal to 24 ft. The macadam may be constructed upon this treated subgrade immediately or the treated subgrade may be used as a low cost road surface for a period of time.

Prior to constructing the macadam, spread the stone screenings, granulated slag, etc., on the treated subgrade, in thickness not exceeding about one-fourth the depth of the thickness of the macadam course. On this, spread the stone course of the macadam and proceed with the construction in the regular manner.

Why these skin treatments on clay subgrades may furnish benefits equal to that furnished by foundations of appreciable thickness is apparent. Clay soil, until after it flows laterally, cannot penetrate the interstices of the macadam. Clay soil cannot flow laterally until after it has attained very low cohesion, due to water absorption. Clay soil in the plastic state cannot absorb water when present unless the clay is manipulated. Until the upper skin of clay, in contact with the under stones of the macadam, is manipulated in the presence of water and softened, the soil located beneath this upper skin is not enabled to absorb water and soften. The water which is apt to cause this upper skin of an impervious clay soil to soften must, of necessity, be water resting on the surface of the subgrade and trapped in the interstices of the macadam. The bituminous treatment prevents this water from both coming in contact with and softening the upper skin of the subgrade soil. The cushion layer of granular material serves to fill the voids in the macadam.

Consequently, this subgrade treatment serves:

- (1) To eliminate the voids into which the clay would enter.
- (2) To eliminate the voids in which water would collect on top of the subgrade.
- (3) To prevent water resting on top of the subgrade from both entering and softening the subgrade soil.

RESULTS OF SUBGRADE TREATMENT IN PRACTICE

Just how much benefit subgrade treatments of this character are apt to furnish is not known at present. It is possible, however, that on subgrades treated in the manner described, flexible pavements not more than 3 or 4 in. thick will prove adequate to carry heavy traffic on sand, and similar pavements not more than 6 or 8 in. thick will prove adequate to carry moderately heavy traffic on properly drained clay and silt subgrades other than of the elastic varieties. When the presence of colloids in appreciable amount in the subgrade require extra thick foundations under macadam, and when porous base courses are used under concrete pavements, the bituminous treatment on the subgrade still remains an essential requirement.

It is hoped that a report of a comprehensive investigation of stabilization of subgrades carried on in Ohio by both Raymond Smith and Professor F. H. Eno will become available during the coming year. A report

of a comprehensive investigation of subgrade treatments carried on by the U. S. Bureau of Public Roads, with the U. S. Bureau of Chemistry and Soils and the State Highway Departments of both Minnesota and Missouri cooperating, is now being prepared. Little of authentic character can be said until these reports become available.

The benefits which are apt to be furnished by subgrade treatments are indicated, however, by the following:

(1) Bituminous coating with blotting layer of sand prevents the annual loss of silt 4 to 5 in. thick from roadway adjacent to a concrete pavement 9 ft. wide in Missouri (according to J. J. Corbett, district engineer of the Missouri State Highway Commission, St. Joseph, Mo.). This suggests the desirability of treating unstable shoulders.

(2) Subgrade treatment with bituminous material covered with gravel 2 to 4 in. thick furnishes a road surface equal in efficiency to a road surface consisting of gravel 8 in. thick constructed on an untreated subgrade in Missouri (according to F. V. Reagel, Missouri State Highway Department).

(3) Bituminous coatings covered with blotting layers of granular material furnish all-year serviceable roads in the Red River Valley, located in both Minnesota and North Dakota (gumbo soil), whereas gravel surfacing on untreated subgrades fails in locations where surface water in adjacent fields causes the subgrade soil to become wet (5).

(4) Waterproofing the subgrade with tar paper serves to prevent cracking in concrete pavements due to certain subgrade soils absorbing water from the concrete when setting (according to R. W. Crum, director of the Highway Research Board).

(5) A subgrade treatment consisting of $\frac{1}{4}$ gal. of bituminous material to the square yard and a blotting layer of 112 cu. yd. per mile on a roadway 30 ft. wide at a cost of about \$500 per mile furnishes better service, produces less dust and has a lower maintenance cost than gravel applied at the rate of 500 cu. yd. per mile, at a cost of \$800 per mile, on untreated silts in St. Louis County, Minn. (Information furnished by Sheldon B. Shepherd, county engineer of St. Louis County).

It should be emphasized in conclusion, however, that:

(1) Subgrade treatments not supplemented by adequate drainage do not serve to prevent loss of stability in silts during the spring thaws.

(2) Treating merely the surface of subgrades does not serve to eliminate the detrimental elasticity possessed by soils containing either mica or organic matter in appreciable amounts.

(3) Bituminous subgrade treatments used under top-soil roads might serve to trap water entering the top of the road surface and thus might cause the top-soil road to soften.

(4) Subgrade treatments essentially are not permanent road surfaces. Therefore, to utilize the full benefit to be derived from subgrade treatments, an attempt should be made to construct upon

them (possibly progressively) road surfaces permanent in character.

(5) Admixtures of bituminous materials, combined with both intensive subgrade manipulation and chemical admixtures, furnish a fruitful field for investigation.

(6) Proper methods of application, amounts of material to be applied and types of bituminous materials best suited to furnish the desired results remain to be disclosed by research to be performed in the future.

(7) A thorough understanding of the physical laws upon which the serviceability of subgrades depends, serves to disclose the possibilities to be furnished by research of this character. Furthermore, these physical laws furnish a basis according to which research yielding fruitful results may be intelligently performed.

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DISCUSSION

MR. C. A. HOGENTOGLER: I shall take but a minute to discuss briefly the occurrence of irregular cracks. It has been customary to consider that all types of cracking in concrete slabs are due primarily to heavy wheel loads, low supporting subgrades or contraction caused by tem-

perature changes in the concrete. Evidence in increasing amount, however, indicates that many cracks develop at least in microscopic form during the setting period of the concrete and are caused by a combination of shrinkage in the concrete and expansion of the subgrade soil due to water absorption. An impervious subgrade treatment should serve to prevent the occurrence of cracking of this character. Cracks which neither begin nor end at a side, at a joint or at another crack in a slab, of necessity must be formed during the setting period of the concrete, because it is a physical impossibility to fracture a rigid material without having at least one end of the crack extend to an edge or to the end of the slab. A bullet punching a hole in a window pane is the result of shear and not bending and this type of breaking does not ordinarily occur in rigid pavements.

CHAIRMAN R. M. SMITH: I am sure everyone will agree that the paper presented by Mr. Hogentogler has been a source of valuable information. It is only to be regretted that we did not know something about this subgrade treatment several years ago, before we built so many miles of macadam. However, it just goes to prove that when we think we know all about highway building, we find that we are only in our infancy and there is plenty to learn. I had hoped that we would touch on piling and its effect in this treatment of subgrades, but I presume it will be discussed in the next paper. I am sure Mr. Hogentogler will be glad to discuss this method of treatment with anyone interested enough to start the discussion.

MR. J. S. BURCH, WASHINGTON, D. C.: About the angle of internal friction. Which angle is represented on the graph? Is it the ϕ , and how may it be determined with respect to the nature of the soil? For instance, does sand have a high angle or a low angle, and how is it with clay?

MR. HOGENTOGLER: The angle of internal friction furnishes an arbitrary means of comparing the resistance possessed by different materials to sliding. When a sample of sand is sheared the resistance required to cause shear, divided by the pressure exerted upon the sand, equals the tangent of the angle of internal friction. For materials possessing both cohesion and internal friction, a quite elaborate test is required to determine the relative amounts of internal friction and cohesion which compose the resistance to shear. The resistance possessed by sands to sliding may be estimated by means of the lower-liquid-limit test. Consequently this test, combined with the centrifuge-moisture-equivalent test, which serves to disclose the capillary properties possessed by sands, furnishes a means for identifying sands with respect to their stabilizing properties. For equal moisture equivalents of 6, for instance, a sand which possesses a lower liquid limit of 30 is apt to prove appreciably more efficient as a stabilizing agent than a sand which possesses a moisture equivalent of only 10.

MR. BURCH: The determination within a certain range rather than an actual determination of that sliding friction?

MR. HOGENTOGLER: Yes, the simple tests furnish an indication, but the relative amounts of cohesion and internal friction can be measured by

an elaborate test designed by Dr. Charles Terzaghi in the laboratories of the Massachusetts Institute of Technology. At present an attempt is being made to simplify the apparatus used for measuring these mechanical properties of the soil.

CHAIRMAN SMITH: The next paper on the program is entitled "Causes and Control of Damaging Frost Action in Shoulders and Subgrades," by Mr. W. C. Buetow, state highway engineer of the Wisconsin State Highway Commission.

Causes and Control of Damaging Frost Action in Shoulders and Subgrades

By W. C. Buetow, Madison, Wis.

State Highway Engineer, Wisconsin State Highway Commission

When this invitation was extended to the Wisconsin Highway Commission to give a paper on this subject, at first we thought we had a message to bring to you, but as we got into the discussion of this paper, we realized what our time limitations were. Gradually a feeling came over us which I can best explain or illustrate by a little story. Some years ago two young fellows started out in the world to make their way, and, making a success, they returned to their home and tried to find their parents. They were unsuccessful for several days. Then they picked up a newspaper and read of a fatal accident. The description of the victim tallied pretty closely with that of their father, so they went to the establishment where this body lay and agreed, after an examination, that it was their father. So they ordered a proper burial, remarking that they would be back to see that everything was carried out properly. The next morning they returned to see that everything was all right, but on closer examination they saw that the victim's lips were parted a little and that indicated to them, because of the teeth, that it was not their father. They said, "it is all off," and left. Just as they passed through the door the undertaker looked at the body and said, "You darned old fool, if you had kept your mouth shut, you might have had a decent funeral." Therefore, I am going to make this paper brief, because we do not know a great deal about the frost-boil actions and their causes, as well as the eradication of them.

HIGHWAYS HAVE PECULIAR AILMENTS

The state I come from, Wisconsin, lies in what is known as "the snow belt," but I do not use this term "snow belt," as it is used in the mountainous regions. Our climate, as a matter of fact, is most wonderful, not only for the few summer months, but for the entire twelve months of the year. This can be ascertained by visiting our state as many thousands of tourists do every year, but, due to the climatic conditions, we find that our highways have certain ailments. I suppose all states find that their highways have peculiar ailments to which they are subject in their par-

ticular part of the country. The ailments of the human race have been curtailed to a very marked degree by research. This child, which is called "public highway," is also subject to various ailments and must be given attention. So far, the advancement made in this respect is only a scratch on the surface. It is only through research that a proper specific can be determined which will alleviate the trouble or effect a temporary cure. We find ourselves, therefore, in exactly the same position as a physician who is able to prescribe a cure after a proper diagnosis, but is unable to tell what should be done prior to the time when the disease fastens its fangs on the victim. What a wonderful time we would all have in this world of ours if we could foretell, in advance, exactly what to do to prevent certain things that will happen. Unfortunately, this is not the case.

As I said before, the state I come from lies in the snow belt, and our climate is most wonderful during the entire year, but on account of variations in the climatic conditions we find that our highways have certain ailments. And I now come to that ailment we have in the northern states, called the "frost boil."

DIFFERENT KINDS OF FROST BOILS

This pestilence strikes down our pavements yearly, but not necessarily in the same spot each year. The same areas in the state have the yearly trouble, but the particular highway may not be impassable at the location where it was the year before. You will say that this is easy to explain. Some corrective agencies were applied the year previous, but what about those spots that just naturally heal themselves? That's a different case for the doctor, and a purely speculative one. Unfortunately, the same doctor has not been retained for a study of the trouble over a period of years. Before the problem can be solved successfully a serious study of soils will have to be made as to their composition and their capillary powers. This, with various drainage problems, will, no doubt, lead us to a solution.

The first step in the diagnosis is to find the location of the trouble. The eruptions, strange as it may seem, usually occur in cuts or near the point where the cuts end and the fills begin. In hilly country the side hill roads are bothered considerably in addition to the lower level roads. While we know from past experience where the boils usually form, yet it is impossible to point to a spot during the summer and say, "here is a spot that will go to pieces next spring." Why the eruptions do not come regularly each spring, even though no treatment is given, is difficult to say, except that nature performs wonders.

There are two kinds of boils, at least, in Wisconsin. The first appears—note I am not positive in this statement—to be caused by a live vein of water just under the subgrade. It usually appears on side hills. Troubles of this kind have in many instances been traced to a lake or swamp area which may be close at hand or miles away. The second type of boil, the kind that makes the most serious trouble, generally appears on the more level stretches of road and where the roadbed is built of a fine, medium clay, superimposed on a nonporous subsoil of exceptionally heavy clay or hardpan. The two types just described are the Wisconsin brand of boils. There may be others, but we are not familiar with them.

Frost boils, as indicated by their name, start forming with the first good freezing weather. If there happens to be a good fall of snow before the cold weather sets in, the conditions heretofore mentioned would not be so bad in the spring. Snow acts as a blanket and prevents the frost from penetrating to a considerable depth. However, in this age, when there is a demand to have the roads open during the winter, frost has an opportunity to reach quite a depth. Snow removal is a detriment in this respect. If there were no ground water present, neither the freezing weather nor snow removal would cause bad conditions in the spring.

The time of the year when the boils start acting is usually in the early spring, when the days are warm and the nights bring a light frost. Naturally, the southern part of our state experiences the trouble the first part of early spring, and the northern part of the state, several hundred miles farther north, is not disturbed some years until as late as June. The time of the year is directly dependent upon the depth of the frost.

ACTION OF THE FROST BOILS

Usually the snow has almost disappeared before the usual signs show on the surface of the semi-rigid type of pavement. With the concrete surface the usual symptoms cannot be detected as readily except when water oozes through the joints or cracks and leaves a finely divided sediment on the pavement. In the unsurfaced and semi-rigid types of road, the entire surface quakes as a concentrated load is applied. Before the frost has gone out sufficiently to start the boil to acting, the frost is drawn out of the upper six inches to a foot of the surface. This much of the surface dries out readily and becomes a hard crust in an unsurfaced or gravel road. A thickness of six inches will sustain quite a load. The surface, from all outward appearances, seems to be in good condition. As the frost goes out below this, there are changing conditions underneath, which soon show on the surface. There are times during the break-up when a person is able to cause quite an area to quake merely by the shifting of his weight. If travel were kept off the highway during this time, the surface would remain intact. The passage of vehicles over these spots causes a puddling action and stirs up the mess underneath the crust.

When the subsoil is worked into a semi-fluid state the surface becomes warped and cracked in places. As soon as this happens an eruption starts with the ejection of the mud by boiling action. Travel, continuing over these areas, breaks through and becomes mired. What a mess then results due to the relief vehicles pulling the distressed ones out. Everyone becomes disgusted with the highways and the highway organization. Each year a lot of free advice is given the department by the laymen about getting away from this nuisance. For instance, we have been told to fix these boils during the summer and fall months, thereby eliminating the trouble in the spring. That is a fine idea, but it probably would take a superwizard to locate the spots that will be troublesome. In one of our northern counties one road became impassable yearly, not in its entire length, but in spots. As soon as one of these spots was remedied the infection broke out in a different place

in the following spring. Before this particular stretch was cured the frost boil was chased half way across the county. This illustrates, in a measure, the nature of the ailment.

The chief cause of frost boils is ground water and the lack of adequate drainage in the soil itself. Water gets into the ground by soaking in from the top or by capillary action. No matter how it gets there it is a damaging element in a road bed. We all know that when water freezes it has tremendous expansion powers. The same condition exists when it is mixed with earth, and it would seem that the earth would be loosened up and, when thawing takes place, the water would escape. This probably would be true if the frost would leave uniformly throughout the road bed. Many other factors change this condition, namely, the snowbanks in the ditches, the vegetation on the shoulders and slopes, and the early thawing, with the incidental early drying out. This last mentioned condition acts as an insulator and prevents rapid thawing downward and toward the center of the road. Thawing, however, gradually is taking place below the traveled part of the road. The freed moisture is surrounded on the sides and bottom by the remaining frozen earth, and cannot escape either to the ditches or to the subsoil. As moving loads pass on the dried out crust we have the agitation mentioned before, resulting in a frost boil breaking out through a rupture in the crust. This describes briefly the causes for a boil forming.

METHODS USED IN ERADICATION

When a frost boil has formed, emergency measures must be resorted to in order to provide travel with a means of passing over and through these spots with as little inconvenience as possible. Draining the center of the boil, of course, is the best. There are several other schemes, such as trenching to the side ditches, by dynamiting down through the frost to the unfrozen subsoil, or by steam jets thawing out the frozen ground. When equipment is not available for these measures, then the moisture should be absorbed by the use of sand, fine gravel or stone. Troughs made of wood or metal are sometimes placed on the surface for the vehicles to travel on during the break-up. This, however, is used only where materials are not available or the boil is too long. Quarter-mile stretches have not been uncommon in some years, but such conditions are gradually being eliminated. The use of proper materials to dry up a boil and to form a crust over the crater is very much appreciated by the traveler. In years gone by anything close at hand was thrown on the affected spot, like hay, sod and cornstalks. Even railroad ties were used. These materials are really a detriment, because all, excepting the ties, while they permit vehicles to pass over rather than through the road, retain moisture long after the entire frost has left the ground. Large rocks or field stones dumped into a boil will help for a year or so, but as soon as the voids become plugged with the soil they do not function any longer, and we are back at the place where we started. In addition, these stones soon find their way to the surface during the ensuing periods of the year.

No doubt a great deal could be done in the eradication of frost boils by means of studying soils and their distribution in the earth work.

Such a procedure, without a doubt, would require a greater outlay of money in the grading work, but would result in less cost over a period of years. The expense of taking care of frost boils during the spring breakup is no small item. Later in the season the surface must be restored at an additional expense. If we add to these items the inconvenience of the traveler, a goodly sum will result.

The best means of water elimination is through efficient subsurface drains. In those soil types that are susceptible to drainage trenches, longitudinally and transversely filled with crushed rock, clay tile, perforated metal pipe and artificial strata have been used successfully. The artificial strata have proved to be the most efficient, but are much more expensive. The process involves the excavation of about 20 in. and laying on the floor of the excavation about 8 in. of sand and gravel. This layer should extend the full width, from shoulder slope to shoulder slope. The grade is then restored by filling, on this layer, with selected earth.

NATURE OF THE DRAINS USED

Heavy plastic clays and other especially retentive soils should not be used. A porous layer of sand and gravel will not entirely shut off but, to some extent, will retard capillary action and collect such surface water as will find its way through the upper strata. Water finding its way to the porous strata can readily flow to side ditches and be carried away. Frost will penetrate to a greater depth than 20 in. or the bottom of the porous strata, thus tending to form boils. Even if boils do form below the 20-in. depth, a crust of this thickness will sustain a considerable load without breaking up. Should the boil begin to ooze the moisture would be expelled into the porous strata and pass through to the side ditches of the road.

The stone, tile and metal drains are used quite extensively. In the denser plastics and retentive clays drains cannot draw water laterally very much. It takes many lines to do much good. Such soils are subject to considerable heaving, and tile lines are readily displayed. The perforated metal pipes do much better in these soils on account of the fewer joints. These methods of subsurface drainage, however, do not function forever. Porous material, covering the tile and perforated pipe, becomes clogged and the voids in the stone drains become silted up. Then the pipes and trenches cease to function and we are again subject to the disturbance of boil action.

In the extreme northern part of the state we have a very heavy, plastic, red clay soil that does not give us trouble. About fifteen or twenty miles inland from Lake Superior the soil changes to a less plastic clay, and here is where the frost boil trouble begins. It ends only when we encounter the sandy section of the state. This shows that the type of soil has considerable to do with the trouble. Until adequate research work has been done, however, we will not be able to rid ourselves of this great plague—the frost boil.

DISCUSSION

CHAIRMAN R. M. SMITH: I am sure every one felt absolutely at home, particularly those from the northern states, when they heard that discussion. It was most interesting and instructive. The paper is worthy of consideration, and I will ask any one who has anything to bring up in connection with it to do so. I am sure Mr. Buetow will be glad to give you any further information he can.

MR. W. C. BUETOW: I would like to make one other statement in reference to frost boils. A few years ago we heard of a cure that was so simple we could hardly believe it. We found, if we put on a layer of 2 in. of gravel before the frost came, it would prevent a great many of the frost boils. I do not understand why a layer of 2 in. of gravel will prevent as many frost boils as it does, but it certainly does marvelous work. I think perhaps the frost boils come on roads that have been worn under heavy traffic. The crust is getting thinner and thinner and the ice goes deeper. The 2-in. of gravel tend to prevent this. Anyhow, the system is simple and easily applied and 4 or 5 in. of gravel will prevent frost boils on almost any road.

MR. R. H. BALDOCK, Salem, Ore.: We also have frost boils in Oregon. As I remember, the speaker stated that, in Wisconsin, they did not have any trouble until spring. Our boils cause rolls 10 to 12 in. high in the middle of the winter. Does that peculiarity manifest itself in Wisconsin?

MR. BUETOW: It only manifests itself in the spring of the year. That is the only time we have these ridges and we feel that they are caused by the weight of travel forcing this stuff up from underneath. It forces it longitudinally, not transversely.

MR. BALDOCK: The ridges in Oregon are all transverse.

MR. BUETOW: Ours are all longitudinal.

CHAIRMAN SMITH: The next paper is entitled "Black Base for City Pavements," by Mr. J. H. Dingle, city engineer of Charleston, S. C.

"Black Base" for City Pavements

By J. H. Dingle, Charleston, S. C.

City Engineer, City of Charleston.

The title of this paper, gentlemen, is a little misleading. The few pages I have here are supposed to contain some bits of experience in municipal work with reference to financing paving construction along railway tracks, and some "black base" work under particularly disadvantageous circumstances.

A history of the roads, streets and pavements of Charleston, S. C., a city now of 73,000 inhabitants which was founded in 1670, most probably would indicate a marked parallelism to that of a majority of the older cities of the United States. Evidences of transition from trail to lane and from lane to street, avenue or boulevard, can be found in the narrow, crooked streets of the older sections, the wider, straighter thoroughfares of the more modern sections and the lack of uniformity in the old, as well as the more regular plan, still with possibilities for

improvement in the new. In character of road coverings also this transition is noticeable, extending as it does through many types, from cobble stone, a matter of civic pride in early days, to modern pavement. Of these types, a variety of interesting exhibits was still extant, even in comparatively recent years.



J. H. DINGLE
CITY ENGINEER
CHARLESTON, S. C.

In its search for a low-first-cost pavement, commensurate with its revenues, Charleston, in the past, has tried plank, oyster shell, pyrites cinders, waterbound macadam and clay-gravel and still has, more as an exhibit, however, than for paving value, a few city blocks paved with cobble stones, brought in the old days as ballast by sailing vessels coming to Charleston for cotton cargoes. In more recent days granite block, vitrified brick, creosoted wood-block, asphaltic concrete and sheet asphalt pavements have appeared. The site of the city having been cut originally by numerous creeks and having included large areas of marsh and mud flats, underground conditions are uncertain and street subgrades vary from virgin soil with good bearing power to filled areas over former creeks with the uncertain support furnished by such conditions.

Prior to 1912 the cost of paving improvements was met by a general tax levy inversely proportional to the other tax requirements of

the municipality. The issuance of bonds for street improvements was impossible since the constitutional limit of bonded indebtedness had already been reached. In 1894, by pooling the revenues of several years, the first sheet asphalt pavement was laid in Charleston along East and South Battery, a pleasure drive about three-fourths of a mile long, previously paved with oyster shell. This pavement consisted of a Rosendale cement concrete base, a binder course 1 in. thick and a 2-in. surface course. The binder was composed of gravel and hot coal-tar pitch in the proportion of between 20 and 25 gal. of pitch to 1 cu. yd. of gravel. The surface mixture was 15 per cent to 18 per cent of asphaltic cement, 65 per cent to 70 per cent of clean, sharp, river sand and 15 per cent to 17 per cent of pulverized carbonate of lime. The pavement was rolled by hand rollers, dusted with hydraulic cement and then compressed by a heavy steam roller. The gutters, for a width of 12 in., were coated with hot pitch and smoothed with hot smoothing irons. A guarantee for five years was included in the first cost and at the expiration of this time, payment of 35 cents per square yard extended the guarantee for an additional five years. This stretch of sheet asphalt, although subject to drenching with, and even submergence under, salt water during storms, when the sea breaks over the adjacent sea-wall, gave excellent results for nearly twenty-one years. In 1915 it was resurfaced with 1½-in. binder and 1½-in. top over the original Rosendale cement concrete base. When removed the old binder was in a disintegrated condition and the old surface was brittle and lifeless.

ILLUSTRATION No. 1



EAST BATTERY, CHARLESTON, S. C. SHEET ASPHALT ON PORTLAND CEMENT CONCRETE BASE. SURFACE IN BACKGROUND LAID IN 1894; RESURFACED IN 1915. SURFACE IN FOREGROUND LAID IN 1925

About 1912 the demand for more and better pavements became insistent and was crystallized in an amendment to the state constitution enabling the passage in 1913 of an "Abutting Property Paving Ordinance." Under this ordinance property was assessed for one-half of the cost of abutting pavement. The city paid, through the general tax levy, for the remaining one-half as well as for street intersections, drains, curbs and sidewalks. Considerable benefit, evidenced by the increased yardage of modern pavement, attended this ordinance, but more progress was demanded, and in 1922, after numerous legal preliminaries, there was enacted the present ordinance under which the abutting property is assessed for the full cost of curb, sidewalks and roadway, including intersections. Where drainage is necessary, it is also assessed for a 12-in. storm-water drain with appurtenances. Paving assessment bonds are issued and property owners are allowed ten years in which to pay their assessments.

From the passage of the first abutting property ordinance down to the present time, asphalt has been the accepted pavement and has increased from seven-tenths of a mile in 1912 to 8.5 miles in 1921, and 55 miles in 1929. During the same period five types of road covering have been eliminated so that, exclusive of earth roads, Charleston now has practically three types of pavement. Charleston's sheet asphalt is generally laid on a cement concrete base, 5 in. thick, the exception being about 50,000 sq. yds., which, because of poor subsoil conditions, are laid on an asphaltic concrete base in the so-called "Boulevard Area." This area extends along the southern and southwestern river front and was reclaimed from the river by constructing a sea wall and filling the area

thereby enclosed with mud and sand, principally mud, pumped from the river bed. The reclamation was completed in the latter part of 1911. The bottom, on which the fill was deposited, was of soft mud. Piles 50 to 75 ft. long had been required in the construction of a foundation for the wall, along which the original depth of water was, in places, as much as 6 ft. below mean low water. The maximum depth of fill, therefore, from the original river bottom to grade, was 14.5 to 15 ft. Grade was $3\frac{1}{2}$ to 4 ft. above mean high water, or 1 to 1.5 ft. above spring tide.

BEHAVIOR OF DIFFERENT BASES

It is noticeable that the manholes for sewers and drains which are on piles have retained their elevation. The road shown below in Illustration No. 5 settled somewhat and evidently pulled apart the top, or surface, of the asphaltic road. I might say also that a street which connects with this boulevard, in which we have sheet asphalt on a concrete base laid exactly under the same conditions as this "black base" material, shows much more exaggerated cracks and differences in elevation. There is not a smooth conformation to the settlement of the subgrade, but a distinct shear where a section of pavement has settled, leaving the adjoining section at its original elevation, an abrupt inequality impeding passage and rendering traffic uncomfortable.

The worst conditions, relative to road construction, existed in the area planned for a river front drive, extending along the sea wall and separated only by the width of the sidewalk from the river, the tides of which saturated the fill to within 4 ft. of grade twice in every 24 hrs. The supporting power of this fill was a matter of conjecture. However, streets were marked out and curbs laid, some on planks. Storm-water

ILLUSTRATION No. 2



MURRAY BOULEVARD, CHARLESTON, S. C. SHEET ASPHALT SURFACE ON ASPHALTIC CONCRETE, OR "BLACK BASE," LAID IN 1925

ILLUSTRATION No. 3



MURRAY BOULEVARD, CHARLESTON, S. C. SHEET ASPHALT LAID ON "BLACK BASE" IN 1925. TWO ROADWAYS SEPARATED BY A CENTER GRASS STRIP. ONE-WAY TRAFFIC ON EACH ROADWAY. CRACKS DUE TO POOR SUBGRADE. TRAFFIC LANE AT RIGHT IN BETTER CONDITION THAN LESS TRAVELED PAVEMENT AT LEFT

drains and sanitary sewers were constructed on pile foundations and a 6-in. after-compression layer of oyster shells was placed as a road covering and added to from time to time. The drive along the river front became popular and maintenance troubles began. In places the subgrade, in wet weather, oozed up through the oyster-shell covering, and again the oyster shells would disappear into the subgrade under the lines of traffic.

ADVANTAGES OF A FLEXIBLE BASE

In 1925 it was decided by the city council to improve the river front drive as well as the other streets in this area and the type of pavement best adapted to the conditions became a matter of serious consideration. The situation seemed to be one in which the qualities of a rigid base, useful under other conditions, would prove objectionable. Settlement was sure to continue withdrawing, from a rigid base, uniform support and converting such a base into a beam, or rather floor slab, of varying span length and characteristics, liable to failure at any time when conditions of load and span should exceed its powers of resistance.

Such a failure had already been experienced, elsewhere in the city, through the rupture, under a heavy truck, of a rigid base spanning an unsuspected cavity. Such cavities, concealed by a rigid base, are practically impossible under a flexible base. The advantages of the latter, with special reference to maintenance of contact between base and subgrade, the non-absorbent qualities of the base and the homogeneity of

base and surface course, useful attributes under wet conditions and the ease, rapidity and low cost of repairs, which conditions promised would be not infrequent. These led to the adoption of an asphaltic concrete base for a sheet asphalt surface.

The roadway was rough graded and a sufficient amount of the poorer material removed to permit the deposit of a 12-in. layer of cinders below subgrade. These cinders were rolled in two 6-in. layers with a 10-ton roller, care being exercised not to lose the roller. Soft spots were dug out and filled with cinders and again rolled. Hauling over subgrade was

ILLUSTRATION No. 4



TRADD STREET, AT SOUTH BAY STREET, CHARLESTON, S. C. SHEET ASPHALT ON PORTLAND CEMENT CONCRETE BASE. POOR SUBGRADE AND CONSEQUENT SETTLEMENT. MUCH TRAFFIC. COMPARE WITH ILLUSTRATION No. 6

prohibited except on plank flooring. On the rolled cinder subgrade an asphaltic concrete base 4 in. thick was laid. The wearing surface was $1\frac{1}{2}$ in. of sheet asphalt.

This "black base" pavement, consisting of 50,000 sp. yds., in a section popular with the natives and of much interest to visitors, carries daily a large amount of pleasure traffic and has cost nothing for repairs or maintenance since its construction four or five years ago. Settlement, not sufficient for discomfort in driving, is evident here and there and in places thread cracks have appeared on the surface due to subsoil conditions. The cracks at any time can be obliterated by the application of a seal coat and, should settlement reach the point of discomfort, depressions can easily, and at low cost, be raised by the application of materials of the same type as those originally used in the road by the bonding of which, with the old material, a coherent structure is maintained.

The driveway on Murray Boulevard, along the river, is divided by a center grass-strip, 12 ft. wide, into two roadways, 19 ft. wide each. One-way traffic prevails on each roadway. It is noticeable that the traveled portions of the two roadways show fewer surface cracks than the portions less frequently used. Surface disturbance is more evident in the paving along the center grass-strip and in the cross-overs where traffic is infrequent.

ILLUSTRATION No. 5



SOUTH BAY STREET AT TRADD STREET, CHARLESTON, S. C. SHEET ASPHALT ON "BLACK BASE." POOR SUBGRADE AND CONSEQUENT SETTLEMENT. PRACTICALLY NO TRAFFIC. COMPARE WITH ILLUSTRATION No. 7

In patching openings in sheet asphalt pavement on cement concrete base, "black base" at times is used where expedition is important or where cement concrete is not readily available.

IMPORTANCE OF PRESERVING PAVEMENTS

The preservation of pavements is next in importance to financing and proper construction. Charleston has made a special effort to discourage the indiscriminate tearing up of pavements and to control repaving where absolute necessity demands that pavements be disturbed. A city ordinance requires that before the commencement of paving operations ample notice shall be given by public advertisement, supplemented by special written notice to public service corporations, advising that certain streets mentioned in the notice are about to be paved and that all work requiring excavation or other disturbance of the street must forthwith be undertaken and must be completed by a definite date also mentioned in the notice, after which date no permit for disturbance of pavement will be issued except in case of special emergency. Back-filling of trenches and repaving are done by city workmen and the cost charged, in accord-

ILLUSTRATION No. 6



CHURCH STREET, CHARLESTON, S. C. SHEET ASPHALT PAVEMENT CONTAINING STEAM RAILROAD TRACKS SET WITH GUARD RAIL AND TWO ROWS OF CREOSOTED WOOD BLOCKS ALONG EACH GUARD RAIL AND ALONG EACH OPERATING RAIL

ance with a regular schedule of prices, to the plumber, contractor or other person or firm opening the pavement. Since, in most of our streets, underground construction needs attention in advance of paving operations, the activities in repairing or reconstructing drains, sewers and gas or water mains, with the accompanying house connections and services which are constructed from mains to curb in all streets about to be paved, leave very little of the old pavement in place and thus preclude surfacing over old granite, brick or other pavements which otherwise might be utilized as bases. In the effort to preserve its pavements, Charleston has attempted to reduce to a minimum the possible damage from street railways and steam railroads. The street railway franchise specifies the use of a grooved girder-rail. Steam roads, crossing modern pavements, use the T rail, provided with guard rail.

VIBRATION IN CAR TRACK PAVEMENT

Experience indicates that vibration, due to street railway traffic, is destructive of asphalt pavement when the latter is in direct contact with the rail. The asphalt, in a short time, is displaced. It curls up on each side of each rail, producing inequalities unsightly to the eye and uncomfortable to drive over. This condition is intensified as portions of the asphalt are broken off by traffic, leaving a longitudinal depression between the rail and a ragged edge of pavement. The first attempt to remedy this involved the use of creosoted wood blocks laid along the rail as a separator or cushion between the rail and the asphalt pavement. The blocks were 3 in. wide and

3 in. deep, the combined depth of binder and top, and two courses were laid as stretchers along each side of each rail, supported by the concrete base and forming a strip 6 in. wide between the asphalt and the rail. The concrete base under the wood blocks was depressed a fraction to allow the blocks to be set in a thin bed of cement mortar and the space on each side of each rail between the web of the rail and the blocks was filled with cement mortar to provide vertical faces flush with the edges of the top of the rail for lateral support of the blocks. The joints between blocks and between rail and blocks were poured with asphalt filler.

WOOD BLOCK REPLACED WITH BRICK

In a few years the tendency of wood blocks to swell in wet weather and shrink in dry weather led to the adoption of vitrified brick for use adjoining the rails. The same construction is followed as in the case of wood blocks except that the use of brick 4 in. deep necessitates a depression of 1 in. in the concrete base. This is obtained with little effort before the concrete base has set.

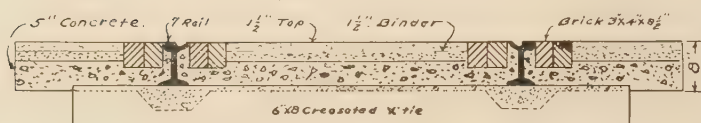
On a recent piece of construction involving sheet asphalt pavement, drain construction and rail renewal on a double-track street, a special type of construction was adopted. The drain, 24 in. diameter and 9½ ft. deep, was located between the tracks, the construction of which, in such close proximity to a fresh fill, caused uneasiness. Old steel rails, 6 in. deep, were cut into lengths of 17 ft., 6 in., sufficient to underlie both

ILLUSTRATION No. 7



KING STREET, CHARLESTON, S. C. SHEET ASPHALT PAVEMENT CONTAINING STREET RAILWAY TRACKS SET WITH TWO ROWS OF VITRIFIED BRICK ALONG EACH SIDE OF EACH STREET-CAR RAIL. LAID IN 1928

ILLUSTRATION No. 8



Cross Section through Tie
South Carolina Power Company
Charleston S.C.

CROSS-SECTION OF PAVEMENT IN CHARLESTON, S. C., CONTAINING CAR TRACKS

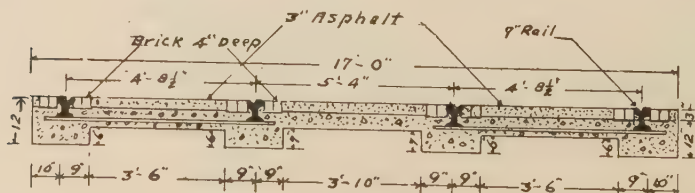
tracks and crossing the new fill. These were spaced at 6 ft. centers with the base of the rail uppermost.

Between each pair of these "rail-ties" were placed Bethlehem steel ties, underlying only one track each, so that long and short ties alternated. The base of the operating rail was welded electrically to each old rail cross-tie and secured by bolted clips to the standard steel ties. The fish plates at the rail joints were bolted with two bolts and electrically welded around the entire perimeter. Incidentally, this obviated the necessity of electrical bonds. All compromise joints, where straight work met special work, and all special work joints were thermit welded. The rigid joints are particularly valuable in the preservation of pavements.

The inner rails were elevated $\frac{1}{2}$ in. above the outer rails by means of steel shims $\frac{1}{2}$ in. thick and electrically welded at both contacts. Concrete was deposited, encasing the tie system and providing the base for the pavement. The general depth of concrete in this track construction is 7 in., which is increased at the old "rail-ties" by 6 in. for a width of 12 in. as a protection and support for the long ties. The minimum thickness of concrete between steel and soil is 2 inches.

This construction has proved quite effective. With the sheet asphalt pavement and a double course of vitrified brick along each side of each

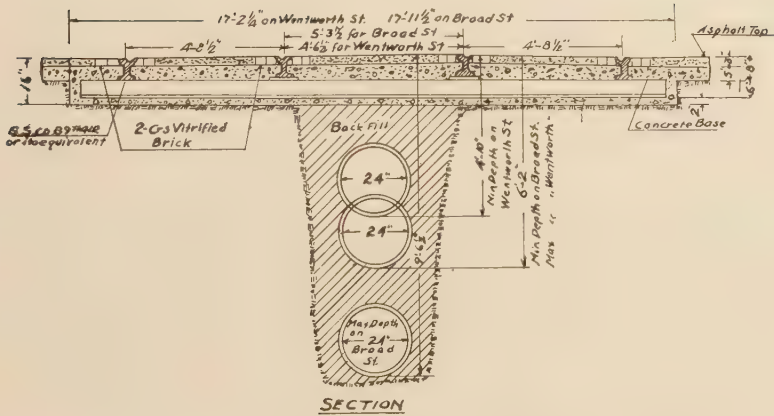
ILLUSTRATION No. 9



Cross Section of Double Track Const.
SOUTH CAROLINA POWER CO.
CHARLESTON S.C.
Scale 1"=2'

CROSS-SECTION OF STREET IN CHARLESTON, S. C., CONTAINING CAR TRACKS

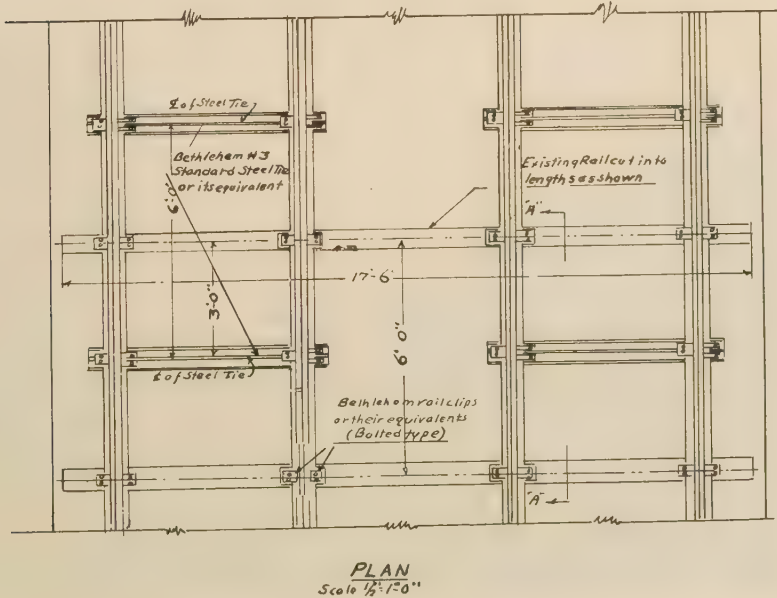
ILLUSTRATION No. 10



CROSS-SECTION OF STREET PAVEMENT CONTAINING CAR TRACKS IN CHARLESTON, S. C.

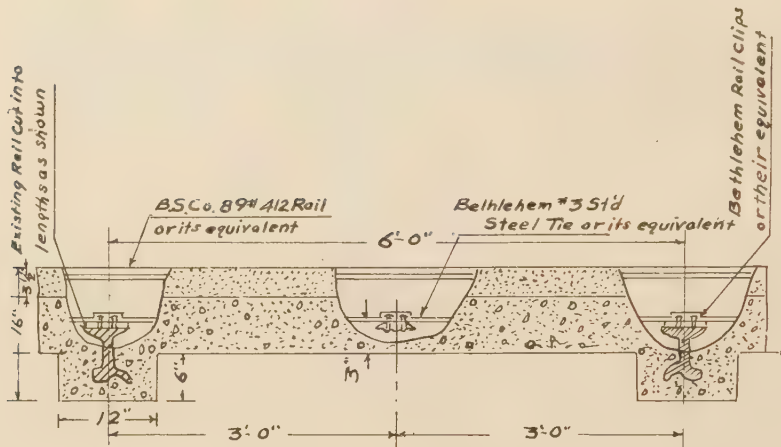
rail, it presents a creditable appearance, is comfortable in use, costs but little to maintain and promises long service.

ILLUSTRATION No. 11



PLAN FOR INSTALLATION OF CAR TRACKS IN ASPHALTIC PAVEMENT WITH CONCRETE BASE, CHARLESTON, S. C.

ILLUSTRATION No. 12



CROSS-SECTION OF ASPHALT PAVEMENT ON CONCRETE BASE SHOWING NATURE OF CAR TRACK INSTALLATION, CHARLESTON, S. C.

ILLUSTRATION No. 13



BROAD STREET, NEAR MEETING, CHARLESTON, S. C. SHEET ASPHALT ON CONCRETE BASE. SPECIAL TRACK CONSTRUCTION WITH VITRIFIED BRICK ALONG THE RAILS

FOURTH SESSION

JOINT MEETING WITH THE ASSOCIATION OF ASPHALT PAVING
TECHNOLOGISTS, OCTOBER 30, 1929, 2 O'CLOCK P. M.

W. J. EMMONS, PRESIDENT, ASSOCIATION OF ASPHALT PAVING
TECHNOLOGISTS, PRESIDING

CHAIRMAN W. J. EMMONS: The meeting will please come to order. The first paper on this afternoon's program is upon a subject which is of great interest to all of us, "Needed Improvements in Paving Plant Equipment and Methods," by Mr. John W. Davitt, chemical engineer, Jersey City, N. J.

Improvements in Paving Plant Equipment
and Mixing Methods

By John W. Davitt, Jersey City, N. J.

Chemical Engineer, New Jersey Asphalt and Paving Company

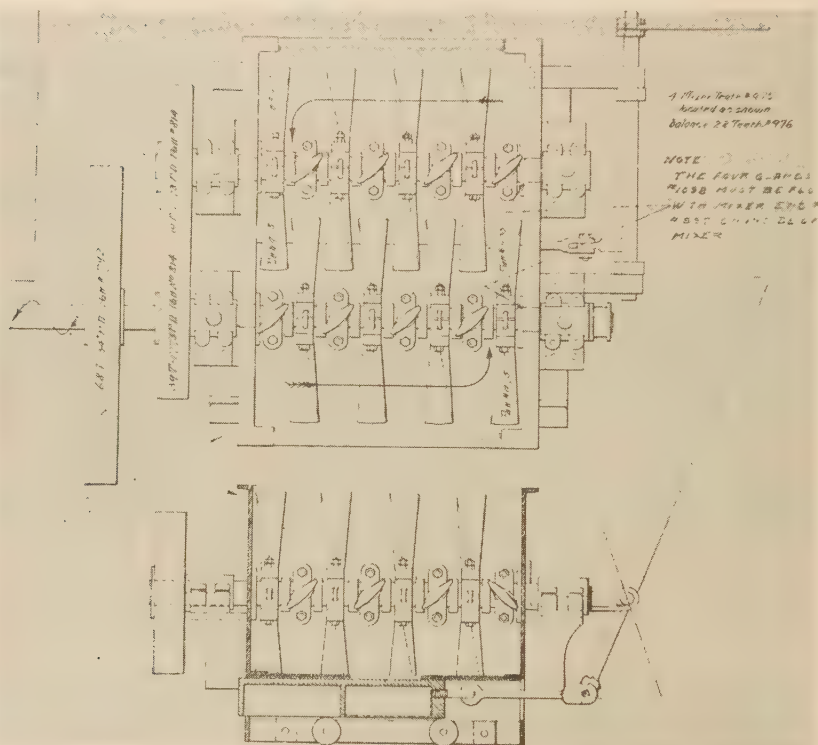
Owing to the limited time allowed for this paper, I shall have to describe the units briefly. Due to competition and the high price of labor, the contractor must have efficient machinery to succeed. Old style plants and plants made from miscellaneous units should better be scrapped. It will require as many men to run a plant of 150 tons' capacity as it will to operate one of 500 tons.

The newer type plants can be operated with six men,—an engineer, a burner man who also does the oiling, a man for the mixer-box, one for the mineral filler, one for the sand and a night watchman. To fill the material bins it is necessary to utilize a crane with clam-shell bucket part of the day.

INTERNAL-FIRED DRUM A STANDARD

The drying unit is the controlling factor in the production of the plant. A few years ago specifications would not allow material to be used that came in direct contact with the flame. Today all new plants are using the internal-fired drum with resulting economy and increased output. At least one-half hour may be saved in the morning and one and one-half hours at closing time, since the drum will cool more quickly. Also the life of the new drum is double that of the old type of drum.

With wet material there is a tendency for the sand to stick to the sides of the drum at the cold sand end. This has been overcome by combining the old and new type of drum; that is, a two-fire plant, with the internal fire at the hot sand end and an external fire at the cold sand end. The furnace, for the external fire, covers about one-half the length of the drum. Holes are cut in the drum and fitted with elbows. This



SHOWING UP-TO-DATE METHOD OF PLACING MIXER TEETH FOR "RUN AROUND" IN MIXER

arrangement allows the heat to pass in and prevents the sand from coming out.

Another type of drum is fitted to allow the gases to pass around the cold sand end before going to the fan or stack. A dust collector, while not a necessity, creates a more friendly feeling with the neighborhood, and soon pays for itself from the fine material collected. The material recovered should be used with the filler and not run into the sand bin, as the practice is at some plants. The amount of dust collected varies with the moisture in the sand.

LOW-PRESSURE AIR-ATOMIZED BURNER

In feeding the drum the bucket elevator is most satisfactory, for it will not carry beyond the designed amount and thus overload the drum. It is better to have it connected with the drum-drive. Then, if the drum slows down the elevator also slows down. In feeding the elevator with stone most any type of bin and gate that can be controlled by the burner man is satisfactory. Feeding the sand is a problem that is hard to control without a man in constant attendance. This is true especially of washed sands.

There are several types of steam or air-atomized burners that are satisfactory for oil under pressure or gravity. For a plant that is short of steam, or that is electrically equipped, the low-pressure, air-atomized burner is very satisfactory. Air is furnished by a motor and fan, or a compressor delivering 1 to 2-lb. pressure. The oil is supplied at a pressure from 15 to 40 lbs. by an electric pump.

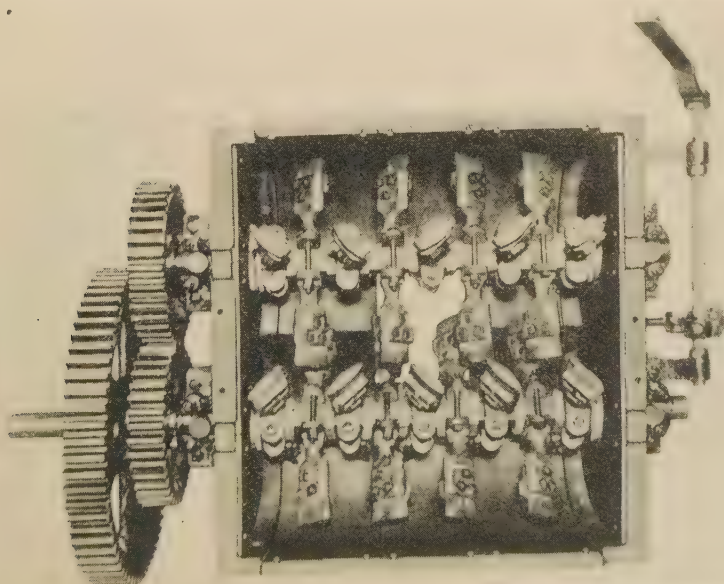
COSTS AND WEIGHT OF FUEL OIL

Two general grades of fuel oil are used for heating at plants, the heavy fuel, 15-16 deg. Baumé, and the lighter, 24 + deg. Baumé. The following table shows the relative costs with weights, etc.:

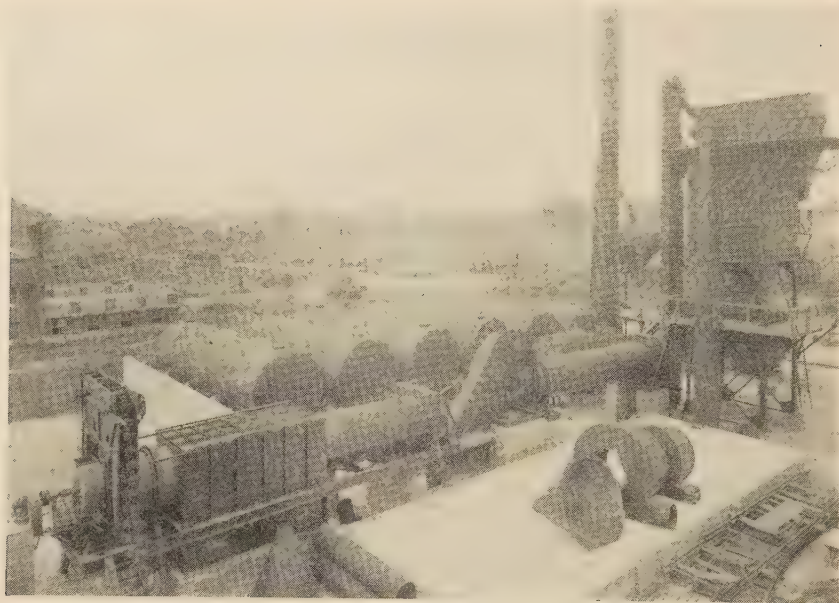
Gravity	Ave.	No. of	Cost	Total cost
Degree Baumé	B.t.u. per gal.	gals. oil required to equal 1000 gal. 15-16°	per gal. at refinery	per day for plant using equivalent 1000 gal. 15-16°
15-16	148,000	1000	.025	\$25.00
24+	142,500	1039	.045	46.76
36	136,500	1084	.06	65.04

A great many firms are losing from \$15 to \$25 a day by not using the proper grade of fuel oil. Heavy fuel oil requires pumping to the burners, but the insurance and fire rules in most places require that all oils be pumped. Then, too, heavy oil must be heated to about 200 deg. F. to work satisfactorily. The cost of steam for heating, however, is negligible.

There are several good pump sets on the market. They consist of two



OPEN MIXING-BOX SHOWING OLD METHOD OF PLACING MIXER TEETH



MIXING PLANT OF THE F. D. CUMMER & SONS COMPANY, SHOWING THE DRUM

pumps and a small heating tank with the necessary thermometer and gages, all mounted on a base. If a plant is located in a neighborhood where tank-wagon delivery is available, a 2000-gal. tank, fitted with 100 ft. of 1 in. pipe coil, will be satisfactory. Care should be taken not to heat the oil to a much greater degree than 200 deg. F. If there is water present, steam bubbles will form and cause the oil to foam over, or the pump will become gas bound if the oil is drawn from the tank by suction.

There is a device for regulating temperature that consists of a tube,—the thermostatic element,—containing a readily expansive, heavy hydrocarbon oil which, on being heated, generates a pressure that is transmitted through a capillary to a tube,—the control element,—where it moves a piston to operate the steam valve. An adjusting screw serves to vary the temperature. This device is accurate within 10 deg. F. in either direction. A 3 x 2 x 3 Duplex piston pattern pump fitted for oil will handle all the burners around a plant. At the far end of the discharge line, near the burners, it is well to have a return line to the tank. This will give hot oil at the burners when starting.

ELECTRIC MOTOR IDEAL POWER DRIVE

For the belt-driven plant the electric motor, slip-ring type, automatic overload release, is an ideal drive and the cost of upkeep is very low. A 2000-yd. plant will average 300 kilowatt hours per day. The electric drive-gear connected asphalt pump is now very dependable and its first cost is cheaper than a steam-driven pump. It has an automatic overload cutout and will not race. It is started simply by pressing a button. A 7-hp. motor will handle a 3-in. pump. Several plants now use a motor

drive for each unit. This is accomplished by reduction gears and overload devices for the motor.

With the perfection of the oil engine, electricity can be generated in a great many plants much cheaper than it can be bought. The plant in the near future will not even have a steam boiler. There may be, perhaps, a small electric one.

In speaking of mixing-boxes, I refer only to the pug-mill type in which the shafts turn in opposite directions. Most mixing-boxes now are steam jacketed. This is a great assistance in starting the work, and when there is a wait between loads. The use of Manganese liners for ends and sides will obviate the necessity of replacement for quite a period of time.

CONVENIENCE OF REMOVABLE TIPS

Removable tips of Manganese steel are a great convenience. They can be changed readily without removing the teeth from the shafts. We all know what a loose tooth means. Care should be taken in selecting the bolts for fastening the teeth to the shaft. Bolts that do not stretch and crystalize with use are necessary. The teeth should be tested for tightness by tapping them with a hammer after the last load for the day. If one is loose it should be tightened at once, before the parts become cool. There are two general arrangements for placing the teeth on the shafts, one where the material is thrown to the center and back, and the other where the material makes a complete circuit of the box.

Messrs. Hubbard and Field, in their paper at New Orleans last year on the "Use of the Stability Test in the Control of Asphalt Paving Plant Output," found that the teeth set for the "run around," resulted in a great improvement in efficiency and thoroughness in mixing, and a greater uniformity in stability. For this method the teeth can be all

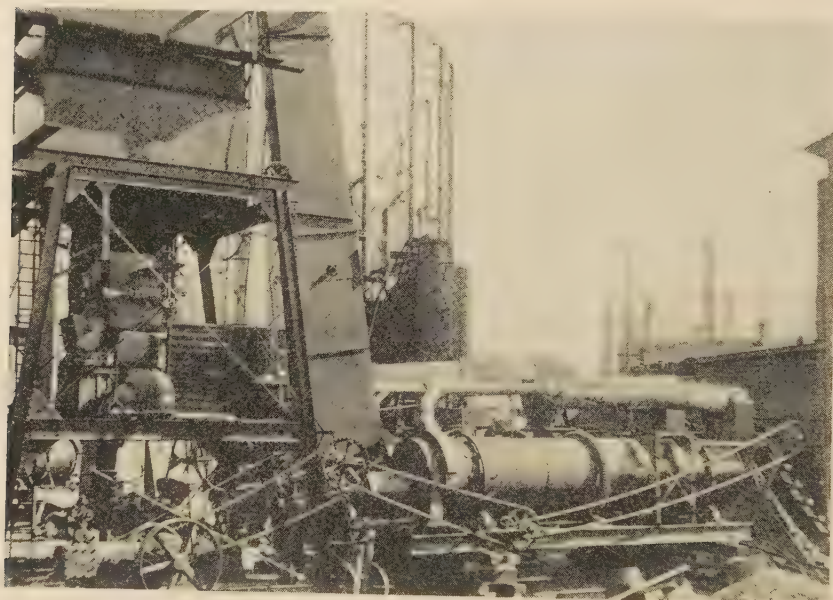


MIXING PLANT OF THE COATESVILLE BOILER COMPANY, SHOWING DRUM

"rights," or all "lefts," with the exception of one set on each shaft. That set must be the opposite in order to throw the material back from the ends. The center bar has been removed from the dumping gate and we now have a full opening gate which allows the mixture to dump quickly.

PROPORTIONING MATERIALS FOR THE MIX

Formerly a uniform mix depended on the men on the mixing platform. An inexperienced man meant trouble and worry for the plant foreman, as well as great delay. At most plants, when weighing the material, you open the gate and watch the pointer on the scales. As the pointer rises you shut the gate. With this method no two men will obtain



MIXING PLANT OF THE WARREN BROTHERS' COMPANY, SHOWING DRUM

the same weight of batch, and often the same man will show a variation in weighing batches. For some time I have been obtaining excellent results by operating a semi-automatic device in weighing sand and stone and asphaltic cement.

The gate lever is opened by hand and held open by a catch which fits over a bolt on the side of the lever. A shaft, which is rotated by a motor, runs under the catches. On this shaft, opposite each catch, is a cam with a throw sufficient to release the catch when the shaft turns. A spring, strong enough to close the gate, connects the lever with the bin. A stopper must be placed back of the gate to prevent it from going too far and opening on the opposite side.

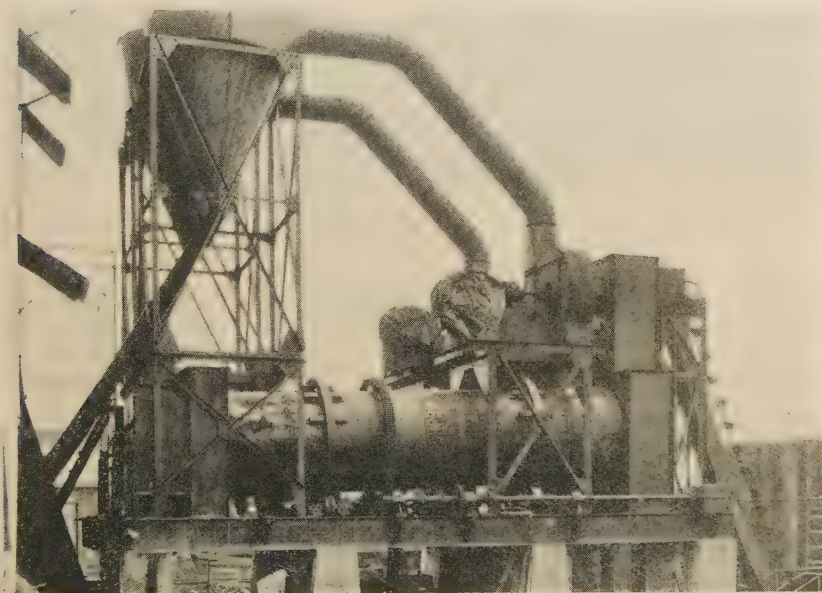
A mercoid switch, connected with the motor through a relay switch, is mounted on the scale beam. When the proper amount of material is in the scale pan, the beam rises, the mercury connects the two points in the

switch, the motor starts and the gate is closed. A similar operation is used on the asphalt valve.

With this method you have the same amount of material each time, irrespective of the person operating the gate. The bucket used for asphaltic cement should be steam jacketed. The inlet and outlet for steam are connected with the bucket by a steam hose. This will not affect the balancing of the bucket.

Instead of dumping the asphaltic cement into the mixing-box, as formerly, I use a butterfly valve in the bottom of the bucket. This is not quite as fast, but it does not retard the general operation, and, I believe, makes a better mix. The mixing-box should be covered. This prevents the filler from blowing away and improves the working conditions around the mixer.

In mixing sheet asphalt, the sand and filler should be mixed for 15



MIXING PLANT OF THE BARBER ASPHALT COMPANY, SHOWING DRUM

seconds before the A.C. is added. If this is done, the total time of mixing to obtain same uniformity is shortened. This was proven by stability tests at Washington, D. C., last year. Only one man is required on the mixing platform.

STORAGE BINS AND MINERAL FILLER

Bins for storing the heated material should be of such shape that there will be no dead spots. This is true especially of the bottom. The bottom should be steep enough for the material to slide through the gate rather than to form a hole above the gate. If there are two gates in the same bin, both should be opened at once when weighing.

The earliest method of adding mineral filler to the mixture was by means of a pail. The bucket elevator, with small storage bin on the



STEAM JACKETED BUCKET AND AUTOMATIC CLOSING DEVICE FOR SAND, STONE AND ASPHALT CEMENT

side of the sand bin, and weighed after the sand, in the same scale pan, is an improvement. This is better than the pail, speeds up the work and dispenses with one or two men.

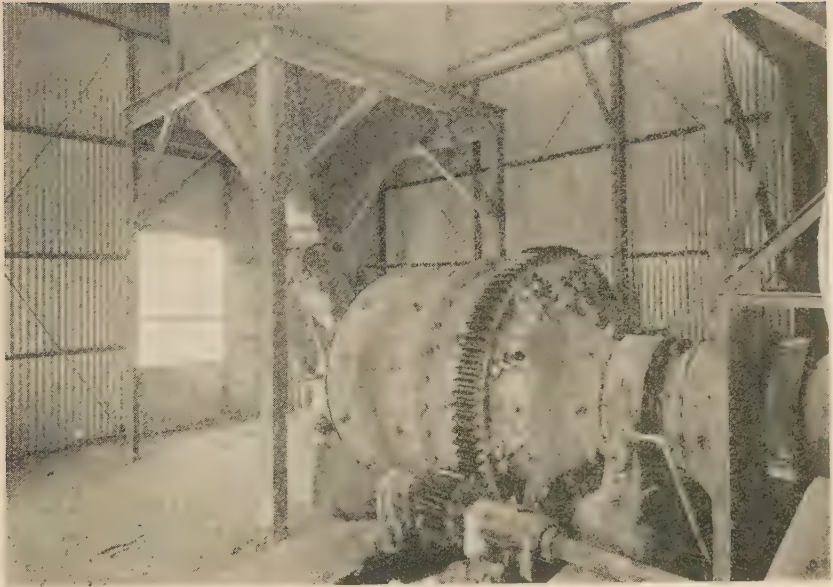
A later device consists of an elevator and bucket holding one charge. This charge is weighed at the foot of the elevator and is hoisted and dumped directly into the mixing-box. This insures exactly the same amount of filler in each batch.

Some plants are now grinding their own filler from the binder stone. The hot stone is ground in a ball mill or hammer mill. Instead of screening, the fine particles are separated from the coarse by means of an air separator, the coarse particles returning to the grinding mill and the finished filler to a bin. This bin can be located above the mixing-box and the filler weighed directly without extra handling. The operation is nearly automatic and requires very little attention. The operation costs and depreciation will be less than \$2 a ton.

THREE METHODS OF HEATING

There are three general methods of heating asphaltic cement. First, the direct fire with a coal, wood or fuel-oil burner under the kettle. These kettles hold about 12 tons, are mounted on wheels and are used for portable plants. Second, the steam melting-kettle fitted with either two or three sets of removable steam coils. By using either of the above the storage tank does not need to be kept at a temperature of over 225 deg. F., and can be heated by exhaust steam. Third, is to have a special coil around the suction in one end of the large storage tank.

For a plant that is driven by electric motor and having burners

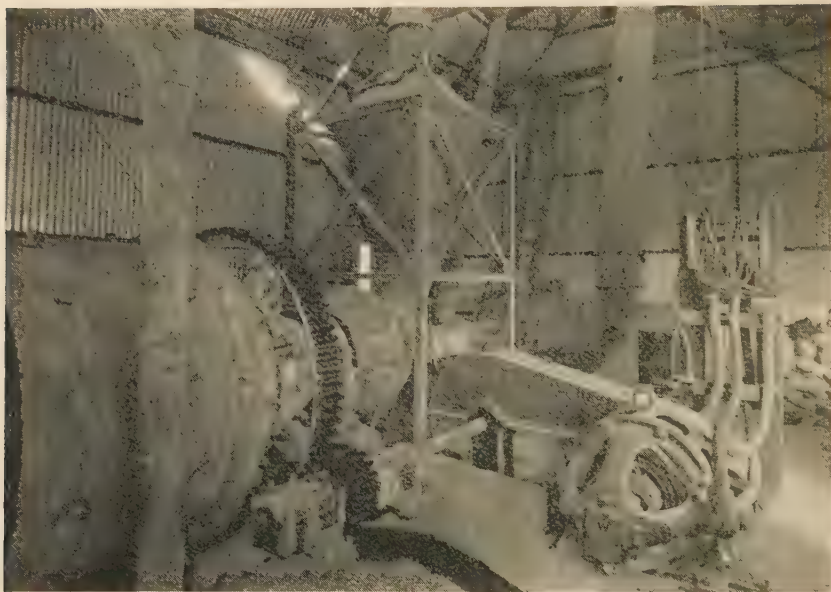


BALL MILL WITH AIR SEPARATOR FOR MAKING MINERAL FILLER FROM BINDER STONE.
SHOWING THE FEEDING END

equipped with air atomizers, we would need steam only for heating asphaltic cement. The roofing manufacturers have had great success in using oil in place of steam for this purpose.



DIRECT ELECTRIC MOTOR DRIVE FOR ASPHALT MIXING-BOX. SHOWING SPEED REDUCER



BALL MILL WITH AIR SEPARATOR FOR MAKING MINERAL FILLER FROM BINDER STONE.
SHOWING THE AIR SEPARATING END

They use a mineral oil, free from carbon and without vapor pressure, or distillate, up to its flash point, which is 600 deg. F. This oil is circulated in the steam coils by a return system.



ASPHALT MIXING PLANT SHOWING ELEVATOR FOR ADDING MINERAL FILLER BY
BATCHES

At one point in the circle it is heated to the desired temperature by means of an oil burner or electric heater. With this system we have a low pressure on the heating coils and, therefore, less danger from leaking coils and no rusting or corrosion.

To prevent hot mixes from sticking to the truck bodies, a soap-and-water mixture in place of kerosene gives good results. A grade of soft soap may be purchased for \$3.50 per barrel of about 250 lbs. A satisfactory mixture can be obtained by adding 50 lbs. of the soap to a barrel of water that has been heated. An eight-quart sprinkling can of this mixture will be sufficient for a 5 cu. yd. body.

CHAIRMAN W. J. EMMONS: The discussion of this subject will be continued by Mr. H. C. McClure, city engineer of Flint, Mich.

Some Needed Improvements in Paving Plant Equipment and Methods

By H. C. McClure, Flint, Mich.

City Engineer, City of Flint

I shall not attempt to discuss the preceding paper. Rather, I intend to give you some idea of a few improvements we have made in our own municipal asphalt plant in Flint, Mich., and to give you some of our experiences there. These experiences may save you some money and do you some good.

With our municipal plant at Flint, we are somewhat happily situated as compared with most municipal plants. We are not handicapped by civil service. We are almost as independent as you contractors are in the way we are able to handle our personnel and the way we are able to handle our improvements. Several years ago we were successful in having established a policy of handling the work exactly as you contractors would handle it and charging all the plant purchase and maintenance expense against the job.

DUST COLLECTORS INSTALLED

As a result of this practice, this year, on our 375,000 yards of 3-in. stuff, we will lay up in our asphalt plant fund around \$65,000 and against the balance of our general construction equipment, \$142,000 or \$143,000. This enables us to go ahead with improvements and changes as we want to do or as equipment people suggest we should do, and follow these through sometimes to a successful conclusion, and sometimes to a conclusion that is unsuccessful.

Some improvements in paving plant equipment and methods have been undertaken and used at the municipal asphalt plant in Flint, during the past season. These improvements and changes in methods, in every instance, have demonstrated that they were well worth while.

The plant consists of two Warren internally-heated, 25-ton dryers, with

a 2000-lb. mixer. The dryers are oil fired and the plant steam is furnished by a 125 hp. coal-burning boiler, which supplies steam at 140 lb. pressure. A maximum month of over 95,000, and a daily average of over 3600 sq. yds. of 3-in. top during August, indicates the possibilities of this plant.

The question of dust elimination was serious, the plant site having been closely built around during the past few years. A rather crude air washing system, taking dryer, elevator and stack discharges, was operated quite successfully for several years, but the dust, amounting to 8 to 10 tons daily, was wasted. This year, the American Blower Company's dust collectors of the latest industrial type were installed.

OLD IDEA IS REVERSED

These collectors reverse the old dust collection idea. Instead of slowing up the velocity of the dust laden air, so that particles can settle out by gravity, they speed up the air a great deal and actually give the minute individual particles enough velocity to throw them to the outside of the dust collector circle. The air discharge is then taken off the center, where very little dust remains. By actual test, the collectors will get better than 99 per cent of the 200 mesh and finer particles in less than 20 seconds after they are picked up. The remaining fractional per cent of extremely fine dust is taken into the old air washer stack and washed down.

The collector fans are connected with the dryer discharge, elevator, mixer and other points, where fine dust particles usually escape. The collectors automatically and continuously discharge directly into the sand elevator, just ahead of the mixer. This process places the dust back into the heated sand mixture, in just the same proportion as it enters at the cold end of the dryer, and gives almost identically the same hot sand grading as existed in the stock pile.

An average of 80 lbs. of dust per minute is reclaimed. This is equivalent to more than 20 tons per day on our present year's run, which, at more than \$5 per ton, not including handling, represents a saving of more than \$100 per day when top is being run. The dust from the binder stone is handled in the same manner, although no saving is figured on binder dust. Plans are now being made to add all dust next year at the cold end of the dryer and produce an *all-hot*, dry-mixed aggregate.

HEAT CONTROL OPERATIONS

Aside from the direct saving in dust cost, and the elimination of the neighborhood dust nuisance, the reclaimed dust goes back at a temperature of more than 225 deg., showing a decided reduction in fuel consumption. Our oil consumption, during the past year, has been less than 0.35 gal. per sq. yd., and our boiler plant burns 1 1/3 tons of coal per thousand yards of top. A stoker installation for this winter will reduce this coal consumption to a still lower figure.

By delivering to the mixer a sand very nearly identical with the stock pile analysis, our chemist is able accurately to proportion his mix from stock pile samples. This is not the case in the ordinary plant where most of the 200 and even 100-mesh sizes are lost in heating. Some experiments

have been made by using a fine pit-run silica dust through one dryer and regular sand through the other with fine results.

The collector fans are driven by variable speed motors. Instead of constantly changing the rate of feeding or heating to control sand and stone temperatures, the operator merely changes the fan control a point or two either way, giving more or less draft, and has obtained far more uniform material temperatures than ever before. The material feeding and oil firing now often run during an entire day practically at a uniform rate. Automatic thermostatic control of the fan speed from the elevator temperatures is now being worked out and it looks as if this will be entirely possible.

With somewhat limited track facilities and a demand of more than 15 cars of material daily at the asphalt plant alone,—to say nothing of the many additional cars of other yard and construction materials,—you can realize that shipment delays would be costly and highly desirable to eliminate, the greatest chance for serious delay being in the asphalt.

NATURE OF PUMPING METHODS

To eliminate this, a 60,000-gallon storage tank was installed. That this installation has been justified from the standpoint of elimination of delays only, we need only to mention that the plant has not been shut down a single hour because of a lack of asphalt since the tanks were connected up. Accumulated shipments, due to faulty railroad deliveries, are also promptly unloaded, releasing track space and eliminating demurrage. The quantity in the storage tank has varied from less than one hour's supply on one occasion to over 50,000 gallons at several other times.

The tank is equipped with general low-temperature heating coils, and a triple nest of center, "hot-spot" coils for heating A.C. to mixing temperatures. These "hot-spot" coils quickly heat and keep the center of the mass at about 300 deg., and the balance of the contents so they will flow slowly toward the center area. It is possible to close the plant down on Saturday afternoon, start steam again about 4 o'clock Monday morning, and have the plant in full operation before 6 o'clock that day.

A single steam-engine-driven pump unloads cars and also supplies A.C. to the plant. Pump supply connections are made to car-unloading lines and to the discharge line from the storage tank as well. Pump discharge lines run to the storage tank and to the plant. The pump discharge line to the tank is fitted with a spring pressure-valve, and the plant line with a quick cut-off valve at the mixer.

Asphalt is shipped in the insulated tank cars. It arrives at a temperature of from 150 to more than 200 deg., depending on the length of time on the road. A half hour to not more than two hours of plant steaming is required before pumping is possible. On Sundays or at night the contents of the cars are pumped directly into the storage tank, allowing prompt release of the cars. During working hours, the cars are emptied both to storage and plant at the same time, as follows:

The governor is removed from the engine. When the cut-off valve at the mixer is open, the drop in pressure allows the engine instantly to speed up and quickly to supply the desired quantity of A.C. When

the valve is closed, the pressure in the lines at once builds up enough to open the spring valve on the tank line and, between boxes, the pump is discharging into the supply tank. The same procedure is followed when pumping from storage, except that the surplus between boxes is pumped back into storage, or, in a measure, recirculated. The cost of 50c. per ton, for the use of insulated tank cars, has been saved in plant time and elimination of demurrage.

As stated above, all asphalt is received in insulated tank cars, which permits short plant-steaming periods before pumping. The supply line to the mixer—approximately 100 ft. long—is double steam jacketed. Instead of having the usual outside steam jacket only, an additional steam line is run through the center of the asphalt line, as well. The comparatively thin cylinder of asphalt around and inside these high pressure steam lines is delivered from the cars directly to the mixer, around 300 deg., and the supply from the tank easily kept at this temperature. Many cars have been used directly from track to plant with no delays in car release.

The mixer liners, of a different composition than formerly used, allow the plant to turn out over 300,000 sq. yds. of 3-inch top before any replacements are necessary. This is much better than we have been able to do in the past. Replacements have been made because the plant was shut down between jobs, and not because, at that moment, the mixers actually were worn through.

NATURE OF LABORATORY EQUIPMENT

Our laboratory is one of the best equipped highway laboratories in our section of the country. It is fully equipped with modern asphalt and general testing equipment. The addition of a Hubbard-Field stability machine, and a 200,000-lb. compression machine, has made it possible for us to follow stability values closely.

The piece of equipment which has saved most, however, is a Toledo special purpose scale of 150 grams capacity, reading directly to 1/10th of a gram. Weights up to this capacity are taken almost instantly. With the Rotap shaker and this scale, a complete screen analysis can be made, and accumulated weights read to 1/20th of a gram, in about the same time as an equally accurate single weight can be taken on the usual even-balance scale. With the stability machine, our chemist has been able to make many more tests of sands and mixtures than would otherwise have been possible, and, by this means, keep a very close check on plant production.

Some very interesting experiments are being conducted, relative to the stabilities which are obtained; (1), by the prescribed laboratory method, (2), by applying 3000-lb. pressure to identical samples, and, (3), by the stabilities obtained on the street under actual construction conditions. We have found that a stability value of around 3000 lbs. obtained by the hand method of making up a mixture-test sample, is increased to at least 4500 lbs. when placed in the compression machine with 3000 lbs. pressure. Samples taken by inserting short steel cylinders in the street before rolling, and later removed, show stabilities for these same mixtures of around 2000 lbs. This street stability is obtained by

the use of a 12-ton, 3-wheel initial roller, followed by 10-ton tandems. The 12-ton, 3-wheeler figures over 350 lbs. per in. width of wheels, dead weight. This heavy roller forces a very uniform mix, as one a little fat will crowd and one a little stiff will crack during the rolling.

These experiments are being carried on further, and it is hoped that reports of some worth-while results will be possible later. Steel rings, made of 1½-in. sections of steel pipe, turned thin, smoothed on the inside, and inserted at the time of rolling, are also being left in the pavement to be removed after several months or a year of traffic compression in order to determine what change in stability occurs under actual traffic conditions. We have found that samples cored from the street show very misleading and varying stability values, due, doubtless, to the disturbance of the outside portion of the samples in cutting, and that the steel ring method gives much better results.

WEIGHING AND FINISHING EQUIPMENT

Other improvements which were contemplated this year, but which, because of our inability to shut down the plant, have not yet been installed, include the installation of platform scales for measuring the asphalt. This scale, which has been purchased, is equipped with a very large direct-reading dial which, at any instant, will record the amount of A.C. in the bucket. The bucket will be mounted on a frame fastened to the platform, and will be capable of being dumped over into the mixer in much the same manner as the asphalt bucket is handled at the present time. The amount of A.C. will always be read directly on the dial, as the weight of the bucket and mounting will be offset by a proper back-weight, and the varying amount of A.C. adhering to the bucket during a day's run will be adjusted at any moment by an auxiliary tare beam. We believe that this continuously-indicating and direct-reading scale will enable the operators to take care of the A.C. quantities very much more quickly and accurately than they can do with the beam-type equipment. A movable dial-indicator is to be fastened to the scale, so that if the quantity of A.C. is varied at any time, the indicator easily can be clipped to the desired point by the chemist, leaving no item of guess work at all in the hands of the workmen.

With the improvement in the plant completed and in use, and generally satisfactory, the street end of the job next has been given attention. The heavier 3-wheeled rollers apparently are giving much better compression and pick out porous spots better than is possible with tandems or any other rollers of the usually smaller weight. The method of taking samples from the street for testing purposes, by means of inserting machined steel cylinders, apparently is going to work quite satisfactorily.

The use of finishing machines, to strike off the binder and top, has been undertaken just recently. Our use of these machines does not cover a very large amount of yardage, but from our limited experience with this equipment, we believe it would be possible to work out from the existing machine, something which would be very satisfactory and will materially reduce the street labor costs. From our preliminary experience with the troubles of adjusting this new equipment to city street conditions, it appears that at least eight to ten men can be dispensed

with on the usual ordinary job. The action of the machine, with a considerable quantity of material ahead of it, is about the same as that of a roller of several tons capacity, and the use of our 3-wheel, 12-ton roller does not show the compacting action of more than a $\frac{1}{4}$ or $\frac{3}{8}$ of an inch at the most. The rollers are able to keep pace with the job much more easily and, on the most recent jobs completed, two rollers have been able to keep up, whereas three were used to keep up with the job before.

UNIFORMITY OF THE MIXTURE

The use of the machine requires a plant of considerable capacity, not less than five or six thousand (6000) yards of 3-in. thickness. The machine also requires that the mixture be uniform in composition. Especially is it necessary to have the mixture uniformly hot. A load that is a little cool and that might otherwise be handled satisfactorily by the shovelers and rakers, under ordinary methods, will tend to drag under the machine, so that, in effect, it gives an additional automatic check on the uniformity of the mix being handled.

We have found the surface produced by the use of the machine to be an extremely satisfactory riding surface. Studies are being made on stability at each stage in the operation with the use of the machine, as compared with the ordinary roller compression alone. We are making no definite plans for the machines until we find how the surface works under traffic.

We believe that dust collectors, asphalt storage, special heating arrangements, special weighing equipment and the additions to laboratories, are necessary to give the best results in asphalt work. These improvements doubtless require a somewhat more permanent installation than exists in a great many instances. We believe that locations, even remotely removed from the street or the road under consideration, can be seriously considered, and longer hauls than have been undertaken in the past can be figured on safely. We believe these hauls safely can be made, with very carefully proportioned and very accurately handled mixtures, many miles from the plant. We believe these distances can be so great that the question of temperatures can be a limited factor.

From our experience in the shipment of asphalt in the insulated tank cars, we believe this objection to loss in temperature for long hauls, can be overcome entirely by the use of properly insulated truck bodies. We believe that a single, good location can serve towns or districts miles apart, and many of the expensive plant moves and set-ups eliminated. The time for papers is limited and discussions of equipment methods are so largely specialized that they are not of general interest. Our superintendent, Mr. Martin; our chemist, Mr. Reedy, and our street superintendent, Mr. Thompson, are all here. They will discuss any details with you at any time, outside of the meeting.

DISCUSSION

CHAIRMAN EMMONS: Does any one have anything to add to these discussions of the plant equipment problem?

MR. F. J. LEDUC, OF MONTREAL, CANADA: Can I ask what provisions have been made in the heat control of the material produced by the im-

proved asphalt plants? I had the opportunity of seeing such control in Europe. But there the time of mixing was so long that the pyrometer used had the time to register the correct temperature of the batch. The time was from two minutes and up. But here, owing to the short period of mixing, the temperature-lag of the thermo-couples was too great for an accurate reading. So special ones had to be built. Now that we know that readings can be made we look for a recording pyrometer that will tell the heat story of every batch, such as it gets in the truck. In doing so we will have a very good check on the inspector in charge of plant control who is supposed to be on the job all the time.

I would like to know if there has been any progress made in that sense in the improved type of asphalt plants described.

CHAIRMAN EMMONS: Can you answer that question, Mr. Davitt?

MR. J. W. DAVITT: Some progress has been made but that is a rather hard thing to work out at present. There is no automatic heat control being used in the plants I have had occasion to visit. The general method is to have the indicator of the pyrometer located where the man feeding the cold material can see it and regulate the flow. Mr. McClure is to be congratulated on the excellent results obtained with his plant. To achieve such results his organization must be efficient and loyal. The speaker, however, is at variance with Mr. McClure on several points. A variable-speed fan for a dust collector is desirable. The object of the fan is to remove the moisture and draw the hot gases through the sand and stone as they cascade in the drum, but too high a speed will draw more air past the burners and require more oil for proper combustion. Also the high speed will remove more fines. The fan run at a speed for proper combustion and removal of moisture should only remove a small amount of fines below the 200 mesh. If this fine material is saved and a proportionate amount is added to each box of top, a greater saving will be effected than if it is returned to the sand bin because, in mixing binder, the dust in the sand has no value. If we could run our plants at a constant feed of material, a change in fan speed would take care of the small change in moisture content that is bound to occur in the material during the day. This would give a constant temperature of output. For maximum output with the burners at capacity the control must be at the feeding end. With the thermo-couple of the pyrometer at the drum outlet and the recording dial where the feeder man can see it and regulate the sand and stone accordingly, a plant can obtain its maximum output with excellent temperature regulation. The speaker fails to see how Mr. McClure's proposed automatic control of fan speed can efficiently compensate for variable feeding. Feeding the mineral through the dust collector would not be satisfactory at the average plant. First, it would require better technical supervision than can be obtained at most plants. Second, there would be a tendency for the material to separate in the bin. This could only be overcome by changing the design of the bin or using the material as fast as it is screened. Neither of these are practical for plants now operating. Why go to the expense and trouble of noting and correcting the varying tare of the asphalt bucket when the tare can be kept constant. The use of an asphalt bucket that is steam-jacketed prevents the asphalt from sticking to the sides and the tare,

therefore, is constant. The speaker uses such a bucket with a butterfly valve in the bottom. It is much easier to operate than the old dumping bucket. The steam jacket should cover the bottom and three-quarters of the sides. The inlet and outlet for steam should be connected by steam hose with sufficient slack so that there will be no interference with the weighing. This method has been in use for a year with good results.

CHAIRMAN EMMONS: If there is no further discussion of these papers, we will proceed with the next, the title of which is "Machine Finishing for Hot-Mixed Pavements in California," by Mr. Charles S. Pope, chief construction engineer of the California Division of Highways.

Machine Finishing for Hot-Mixed Pavements in California

By C. S. Pope, Sacramento, Calif.

Chief Construction Engineer, California Division of Highways

This paper relates to the use of mechanical means for spreading, raking and finishing hot asphaltic mixture for highway and street paving. The information presented herewith was obtained in a working period of about three years, during the construction of some 250 miles of asphaltic concrete surfaced highways and thousands of square yards of city streets. The purpose of this paper is not to provide a comparison between the asphaltic type of pavement and any other type, but rather to describe an important advance in improved structure for the asphaltic type and a more economical construction which has been made possible by the introduction of the machine finish.

The advantages which have become apparent and the improvements in asphaltic construction which have followed upon the introduction of mechanical spreading and finishing have been summarized as follows:

- (1) Removal of limitations on plant capacity, due to inability to handle large tonnages on narrow highways.
- (2) Decrease in unit costs of asphaltic mixture, due to quantity production and quantity handling on the street.
- (3) Greater uniformity in the structure of the asphaltic paving base and surface.
- (4) Decrease in surface roughness to a point where there is now little difference in this respect between the best laid asphaltic type and any other type of pavement.
- (5) Production of a uniformly smooth non-skid surface which will be safe in any weather for a number of years.
- (6) Elimination of poor workmanship through the substitution of machinery for hand labor on all of the more important phases of the work.
- (7) Reduction in rolling due to the particular arrangement of the paving mixture previous to rolling.
- (8) Decrease in plant and street costs due to mass production and

decrease in general contract costs due to speed of operations as a whole.

In this mechanical age, it may seem strange to you, as it does to me, that contractors were so many years in adopting the use of power-operated spreading and raking machines for asphaltic concrete. Similar machines were readily accepted for producing smooth, well compacted concrete pavement, but the practical asphalt paving man always visualized innumerable difficulties which would assail him if he attempted to use similar machines on his work. Proposals that it was feasible to spread and rake asphaltic mixtures with machines were met with many objections, since proved unsound. These objections impeded the general adoption of mechanical spreading for two or three years in California at least, after it was first suggested.

During 1924 or 1925, spreader-boxes for spreading macadam rock came into general use and their success gave rise to our opinion that these boxes might be used to spread asphaltic concrete base, if contractors could be induced to try them. Their use on the first job on which they were tried allowed the contractor to take off a number of shovelers so he was entirely agreeable to the next experiment, which was to attach rakes to the spreader-boxes to rake out the mix. This improvement allowed the contractor to take off one or two more men and convinced us that asphaltic concrete could probably be raked and spread by machine methods.

Our spreader-boxes were not so economical on the thin 1½-in. surfaces we were laying in 1926, so we investigated the use of a large drag-rake spanning the entire 20-ft. width of roadway to be followed by a strike-off screed. These implements were at first drawn by hand and later by horse power. Both implements operated successfully and gave us a surface smoothness superior to anything we had been able to obtain by hand raking methods, but did not tend to increase plant output.



C. S. POPE
CHIEF CONSTRUCTION ENGINEER,
CALIFORNIA DIVISION OF HIGHWAYS

EARLY DEVELOPMENT OF FINISHING MACHINE

Through the cooperation of one of the larger road machinery manufacturers, we secured a standard concrete finishing machine and proceeded to remodel it at our own expense, and thus completed the first attachments for raking and finishing asphaltic concrete by mechanical means. This machine was furnished on trial by the state to one of our contractors engaged in resurfacing a 10-mile section of highway. The working out of the usual defects which seem inherent in a new machine caused us more or less concern but, in the end, the machine got down to work and turned out an excellent job which showed a roughness of about half

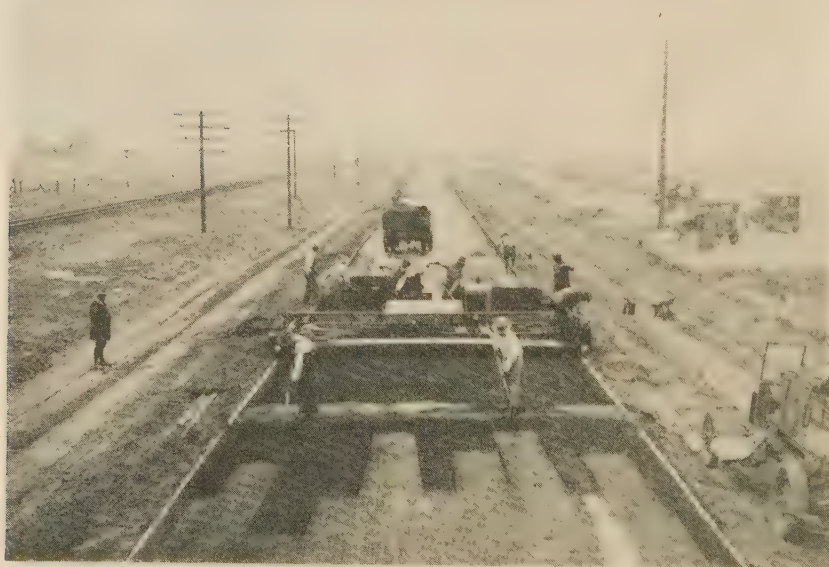
of what we had been getting by hand raking. The successful use of this machine was followed very shortly by a decrease in our costs of asphaltic concrete paving. So much for the early history of the development of the raking and finishing machines.

OBJECTS SOUGHT WITH MACHINE FINISHING

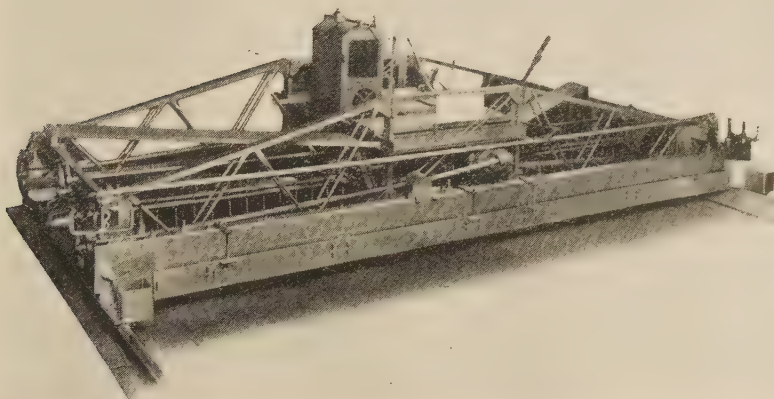
The earlier purposes sought in the use of machines for raking and finishing asphaltic concrete pavement were several. It was desirable to increase the amount of material which could be handled on the road beyond what was possible by hand spreading. Plant capacity could be increased by building larger plants and hauling equipment could be handled on the road, but because of the nature of the material it did not seem possible to place enough shovelers and rakers on a 20-ft. road to handle the greatly increased tonnage required for economical work. In other words, the spreading and raking operations constituted the bottle-neck of the job.

It was desirable that smoother pavements be laid because of the unfavorable comparison which constantly arose between portland cement concrete pavements smoothly finished by machine methods and asphaltic pavements still finished by hand raking. It was desirable that a non-skid surface be constructed which, while smooth, would still afford as safe driving in rainy weather as was claimed for the portland cement concrete. It was desirable to incorporate in the pavement construction such

MACHINE FINISHING HOT MIXED PAVEMENT IN CALIFORNIA



THE PICTURE SHOWS TRUCK BACKING UP TO SPREADER-BOX OVER A BASE WIDENED WITH ASPHALTIC CONCRETE AND PAINTED WITH EMULSIFIED ASPHALT. THE RAKING AND FINISHING MACHINE IS SPREADING SURFACE, LEAVING THE TYPICAL RAKE MARKS AFTER ROLLING. THIS MACHINE HAS THE SLIDING TYPE OF RAKE

ASPHALT RAKING AND FINISHING MACHINE USED BY CALIFORNIA DIVISION OF
HIGHWAYS

(PENDULUM TYPE OF RAKE)

qualities as would insure a long life and freedom from objectionable waviness.

The state was engaged in surfacing with asphaltic concrete, a considerable mileage of state highways which had been constructed of portland cement concrete, usually 15 ft. in width and 4 in. in thickness. An unusual feature of this pavement was its high crown which averaged about $2\frac{3}{4}$ in. or about 3 per cent of the half-width. This high crown eventually added about 1 in. additional average thickness for leveling course over the 15-ft. width. Due to the enormous increase in traffic, to faulty foundations, to under-design of the slab and other causes, a considerable mileage of pavement began to show distress as early as 1916 or 1917 and the state began a program of reconstruction of these pavements to a width of 20 ft.

USE OF ASPHALTIC CONCRETE

Highways in especially bad condition, or which are subjected to truck traffic, or to unfavorable climatic or topographic conditions, were resurfaced with portland cement concrete, while those in better condition or which are located in the valleys or other more favorable locations were surfaced with asphaltic concrete. The asphaltic concrete type of asphalt pavement has been chosen generally in California because of its greater economy and durability and also from the fact that it presents a non-skid surface for a longer time than other plant-mixed asphaltic surfaces. In modern resurfacing operations, because of the greatly increased output, great care is necessary in planning to insure smooth co-

ordination between the plant, the hauling equipment and the spreading and rolling operations.

EQUIPMENT AND PLANT ARRANGEMENT

I will refer briefly to certain plant arrangements which have a bearing on our practice. A plant of considerable capacity is desirable and common practice in California at the present time has fixed on plants producing from 2500 to 5000 lbs. per batch as the economical size. Such a plant will produce up to 65 batches per hour, if properly arranged, and average outputs of from 500 to 800 tons per day are not unusual. While our specifications limit output to 65 batches per hour, the number may be increased, should our laboratory and field investigations indicate that improved methods introduced by the contractor will produce a satisfactory mix in a shorter mixing cycle.

We have found it desirable to premix all of our aggregate before it is passed to the proportioning bins. This is accomplished either by mixing in layers at stock-piles, or else by means of chutes, which deposit layers of coarse and fine aggregate on a belt, running under the storage bins, which feeds the dryer. Weigh-boxes are always placed with their outlets at right angles to the mixing shafts of the pug-mill instead of parallel with the shafts, since the latter arrangement has a tendency to defeat complete mixing of the different sizes of aggregate.

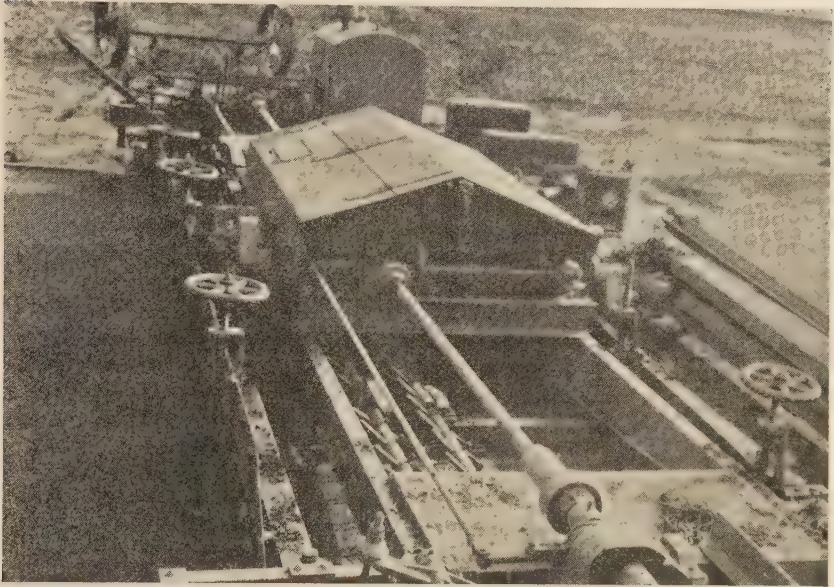
Because of the precarious condition of many of our portland cement concrete pavements, it usually is required that all hauling be done with pneumatic tired trucks. Since the usual load of mixture varies from 5

MACHINE-FINISHED ASPHALT ROAD



MACHINE-FINISHED ASPHALTIC CONCRETE PAVEMENT BUILT BY CALIFORNIA DIVISION OF HIGHWAYS

ASPHALT RAKING AND FINISHING MACHINE USED BY CALIFORNIA DIVISION OF
HIGHWAYS



THIS MACHINE IS AN EARLY ADAPTATION OF THE RAKING PRINCIPLE AND WAS AFTERWARD CONVERTED TO THE SLIDING TYPE. (RAKE TEETH ARE REVERSED FOR CLEARANCE)

to 6 tons, the dual type of tire is in common use. Trucks are usually fitted with convenient coupling devices placed forward of the middle of the truck for ease in attaching the chains by which the spreader-boxes are drawn.

Two usual types of spreader-boxes are in common use, one of which is equipped with skids on which it is dragged forward and the other is supported by means of rollers. Both are equipped with more or less satisfactory gates extending the full width of the back to permit spreading the mixture to the proper thickness. Some difficulty is experienced in making the ribbons of mixture deposited by the spreader-boxes lap over each other without rock pockets developing. One of the best methods to secure this result is to cut holes about 6 or 8 in. square in the ends of the spreader-box near the front of the box which will allow sufficient average mixture to run out to make the junction of the ribbons satisfactory.

SIDE-FORMS AND RAILS USED

We have found spreader-boxes economical and satisfactory whenever a uniform thickness of surface of considerable depth is to be spread. Some contractors claim little saving where a surface less than 3 in. loose is to be spread. In spreading the leveling course, contractors have resorted to numerous ingenious methods of spreading the surface of the course parallel with the true surface.

Since it is now our common practice to require that side-forms be left in place, such forms are of wood, usually a commercial, 3 in. in thickness

and as deep as the pavement. They are supported on hubs at 4-ft. intervals and are staked securely to prevent lateral movement. We require all forms to be surfaced on both edges. While it is quite possible to spread base or leveling course from the wooden side-forms, it is not possible to spread surface with spreading machines as at present designed.

It is necessary to make an allowance for compression and for this purpose it is common practice to lay flat steel rails about $\frac{3}{4}$ inch to $\frac{7}{8}$ inch in thickness, by $2\frac{1}{2}$ inches to 3 inches in width, on top of the wooden side-forms to elevate the finishing machine a sufficient distance above the side-forms to allow for compaction during rolling. These rails usually have a V-shaped, or tongue and groove, connection with each other to preserve alignment and are about 10 feet in length. Usually three or four sets of rails are sufficient on the average job, as they are taken up and moved ahead as the work progresses. It is usual to nail the rails temporarily to the side-forms.

TYPES OF FINISHING MACHINES

Two types of finishing machines are now in use in California, both of which will spread, rake and finish asphaltic concrete. Both types of machines are motor driven and consist essentially of front and rear screed-plates set about 10 feet apart, having a motion transverse to the pavement at the same time that the machine advances along the side-forms. The raking elements are set in between the screeds and consist of steel pins set in heavy pipe as described elsewhere.

We require not only spreading but also raking and respreding by the rear screed on all of our work and in this respect our practice differs somewhat, I believe, from other localities where spreading only without raking is a usual practice. Since we have not tried our machines on sheet mixtures, I am unable to say from actual experience whether raking of these mixtures is essential with a screed machine, but from a large experience in laying sheet asphalt by hand methods I would consider raking such surfaces as essential as raking asphaltic concrete.

The two types of rakes mentioned, which I will designate as the "pendulum type" and the "sliding type," represent the different ideas of the manufacturers but they perform similar work. The rake teeth, which consists of steel pins from 8 inches to 14 inches in length and $\frac{1}{2}$ inch to $\frac{5}{8}$ inch in diameter, are set 6 inches or less apart, in two lines of double-thickness pipe of 2 to $2\frac{1}{2}$ inches nominal diameter. The teeth are adjustable for projection and are fixed in place with set screws. The rake assembly extends the width of the machine, 10, 15, 20, or 30 feet as the case may be.

The essential difference in the two types of machine now in use is the method of raking used. In one machine, the rake teeth swing with a pendulum motion in opposite directions, which stirs up the mixture in line with the direction of travel. In the other machine the entire rake assembly slides backward and forward between guides, the teeth plowing under and lifting the mixture at each forward stroke, and, on the backward stroke assisting slightly perhaps the forward movement of the machine.

Both the pendulum and sliding motions are induced by means of an eccentric connected to a counter shaft and operating crank arms which swing the rake's teeth or cause the whole raking element to slide. The second method has, I think, certain advantages over the first, especially for thin surfaces. The teeth are set to rake at from 16 to 20 strokes per minute and have a travel independent of the forward motion of the machine of from 4 to 8 inches. It is not desirable that the rake speed should be too fast or the stroke too short. The sliding type of rake may have a longer stroke and be slower than the pendulum type.

Essential features of the raking are the lifting of the coarser aggregate to the surface of the mixture and the formation of compression ridges. The coarse aggregate, being lifted to the surface, allows it to be reembedded in the immediate wearing surface by rolling, and thus forms a non-skid surface. The compression ridges between the furrows left by the rake teeth have a tendency to assist compression without distortion or travel in the mixture since the ridges are flattened out sidewise by the roller instead of being driven ahead by it.

PAVING OPERATIONS ON THE ROAD

The paving operations in the construction of base and surface are as follows: Paving mixture, heated to approximately 280° F., is brought to the road in pneumatic tired trucks of 5 or 6-ton capacity. If a leveling course is to be laid on old concrete, a paint coat of emulsified asphalt first is applied to the concrete base. The trucks are backed up to spreader-boxes and are attached to them by means of a quick, detachable chain hitch.

The mixture is spread roughly about 2 inches thicker than it will be left by the finishing machine and at once is spread to a uniform thickness, using the screeds of the finishing machines only as a usual thing. Some operators use the rakes also as they think they assist compression. Rolling is begun as soon as the machines have spread a sufficient amount of material. Practically no hand work is required on the base mixture.

Base mixture usually is carried forward for such a distance as to allow a full day's run on surface, or for even a longer distance, so that it will not be necessary to make so many shifts of the finishing machine. On one large job, at present under construction, two finishing machines are in use, one on base and one on surface, which obviates the necessity of moving either one back on the job. Machines usually are moved off the pavement at night to permit its use by through traffic.

Surface operations follow closely on the methods used in constructing base, but with a number of additional operations. It first is necessary to lay steel rails, $\frac{3}{4}$ inch to $\frac{7}{8}$ inch thick, on top of the side-forms, as hereinbefore described, to give the screeds the proper elevation above the side-forms, so as to allow for compression in rolling. The screeds, which are cut at the center, are adjusted to the correct crown by means of hand wheels. The rake teeth are lowered into the mixture and, in the sliding type, are set at an angle of about 45 degrees.

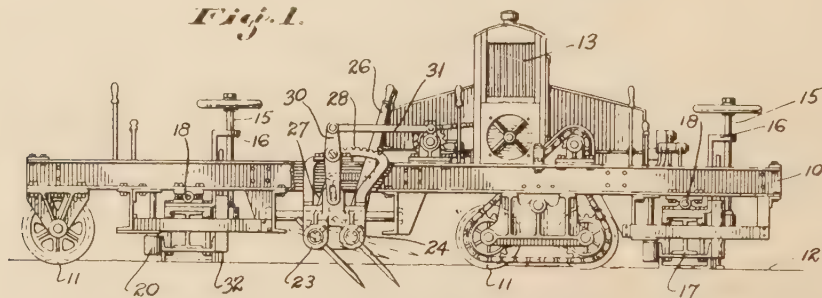
During the paving operation it is desirable to carry a wave of mixture about half the height of the forward screed in front of that screed and a smaller wave of mixture in front of the rear screed. With the

machine in operation, the rakes are forming ridges and furrows longitudinal with the road and the rear screed is just knocking the top off the ridges, leaving coarse aggregate exposed for rolling. The machines usually are equipped for four-wheel drive and will operate at a forward speed up to 10 feet per minute.

NATURE OF ROLLING OPERATIONS

Rolling is done with 10-ton macadam rollers for the first compaction, followed by 6 to 8-ton tandem rollers for final smoothing. Following the first rolling of the surface, our customary practice is to scatter asphalt-coated stone chips, passing $\frac{3}{8}$ inch and retained on $\frac{1}{4}$ inch, over the surface to fill any small voids which may be left in the surface and to provide additional assurance that the surface will be of uniform non-skid texture. Rolling is then continued until no more compaction is possible and the surface is as smooth as it can be made.

Fig. 1.



DIAGRAMMATIC DRAWING OF ASPHALT RAKING AND FINISHING MACHINE USED BY CALIFORNIA DIVISION OF HIGHWAYS

Surface smoothness is checked during construction by several different methods devised by ingenious resident engineers. The simplest method, of course, is to use a 10-foot straight-edge, but, as this requires a good deal of stooping, other means have been devised. One automatic device consists of a straight-edge on three wheels, so arranged that a rise or fall of the central wheel of more than $\frac{1}{4}$ inch rings a bell. Another has a similar bell arrangement but the straight-edge consists of two sled runners. Another is a weighted sled which scores the high points as it is dragged after the roller.

The official record of roughness, however, is recorded on a vialog, or roughometer, attached to an automobile operating at 20 miles per hour. This machine is left constantly calibrated by checking its operation over two or three standard sections of pavement which have been run over many times and on which the roughness has been accurately determined.

The following tabulation indicates the average smoothness we have obtained on some 200 miles of asphaltic concrete pavement laid in the last five years:

<i>Year</i>	<i>Miles Laid</i>	<i>Roughness</i>		<i>Remarks</i>
		<i>Index</i>		
1924	23.84 mi.	30.1		Hand finish
1925	24.11 mi.	33.2		“ “
1926	49.34 mi.	24.1		“ “
1927	35.35 mi.	25.2-14.6		Machine finish begun
1928	60.81 mi.	30.9-14.7		

We have been able to reduce the roughness to as low as eight units on some especially well finished jobs without sacrifice of the non-skid feature. We find that roughness increases with each year a pavement is in use. One of our asphalt pavements laid three years ago with a roughness index of 11 now has a roughness index of 14.

OUTPUT OF PAVING PLANTS

The introduction of finishing machines, as stated before, has greatly increased the average tonnage output of paving plants and also has decreased the cost per ton, as shown in the following tabulation:

<i>Year</i>	<i>Tonnage</i>	<i>Per 8-hr.-day</i>	<i>Average Cost</i>
	<i>Max.</i>	<i>Average</i>	<i>Per Ton</i>
1924	244	194	\$7.27
1925	319	214	6.43
1926	388	333	5.13
1927	366	352	5.68
1928	574	404	4.89

Naturally, this increase in output has required larger plants and, where a 1500 or 2000-pound batch-box was the usual size in 1924, we are now using batch-boxes up to 5000 pounds capacity, with the cost of the plant in proportion.

NATURE OF THE MIXTURE USED

The average asphaltic concrete mixtures we use for base and surface show the following gradings:

<i>Pass</i>	<i>Base Course</i>	<i>Surface</i>
2½	90-100	.....
1¼	65- 75	90-100%
¾	50- 65	75- 90
½	.....	60- 75
No. 3	30- 40	40- 55
No. 10	20- 30	28- 36
40	12- 20	23- 27
80	6- 12	15- 20
200	2- 4	7- 11
A. C.	4.5- 5.5	4.5- 6.5

Stone dust is used in surface only and usually is about 4% of the total mix. The modern methods of conveying, heating, proportioning and mixing are followed and do not form a part of this paper.

Average costs of materials at our mixing plants are about as follows: Fuel oil, \$1.50 per barrel; asphalt, \$15 per ton; stone dust, \$6.50 per ton; sand, \$1.50 per ton, and rock, \$2 per ton.

COST OF LAYING ASPHALTIC CONCRETE

The following comparisons of the cost of spreading asphaltic concrete by hand and by machine were taken from two jobs completed within the last two years:

	<i>By Hand</i>	<i>By Machine</i>
Output.....	300 tons per day.....	600 tons per day.....
Labor:		
Foremen	(1 at \$8.00)...\$8.00...	(1 at \$8.00)...\$8.00
Machine operators.....	(1 at 8.00)... 8.00	(1 at 8.00)... 8.00
Shovelers	(8 at 4.50)...36.00...	(4 at 4.50)...18.00
Rakers	(1 at 7.00)... 7.00...	(1 at 7.00)... 7.00
Rakers	(2 at 6.00)...12.00...	(1 at 6.00)... 6.00
D u m p m a n or		
Spreader-box.....	(1 at 4.50)... 4.50...	(2 at 4.50)... 9.00
Railmen	(2 at 4.50)... 9.00...	(2 at 4.50)... 9.00
Screenings	(2 at 4.50)... 9.00...	(2 at 4.50)... 9.00
Tampers	(1 at 4.50)... 4.50...	(1 at 4.50)... 4.50
Totals	(16) .....\$81.00...	(15) .....\$78.50
Spreading cost per ton.....	\$0.27.....	0.131
Machine rental per day.....		15.00
Gas and oil per day.....		1.20
		\$16.20
Cost of machine per ton.....		\$0.027
Total cost of spreading by machine per ton.....		\$0.158

Three hundred tons per day would have been a good day's work for a hand crew, but six hundred tons per day is not an unusual day's work for machine spreading.

In conclusion, I wish to predict that the more extensive use of machinery in the construction of asphalt pavements has opened a new era for this material. With the growth of knowledge as to the economic and engineering considerations which should govern the selection of pavement types, the use of asphalt pavements in their proper locations will reach proportions sufficient to satisfy their most ardent advocates without detracting from the merits and usability of other types of pavement in their proper environment.

CHAIRMAN EMMONS: I would like to ask Mr. C. L. Donovan also to discuss this subject.

Use of Finishing Machines on Various Types of Asphalt Pavement

By C. L. Donovan, Cleveland, Ohio

Engineer, Paving Department, Lakewood Engineering Company

The tremendous increase in the use of machines for finishing bituminous surfaces, on both state highways and city work, has been due largely to the recognized saving in labor and time, and to the admitted better quality of the finished work. Not only has machine finish made asphalt roadways more accurate as to riding surface and crown, but it has also provided a more even distribution of material, thus increasing the quality of the pavement. Finishing machines, at this writing, have been used successfully on practically all of the so-called "hot mixes," and, of late, have been used with marked success on such cold mixes as "Kyrocks." It appears that any mix that is suitable for hand raking can be finished easily and successfully by machine.

At the present time machines are operating where various sizes of plants are in use. Some of the larger plants have a capacity of nine hundred to a thousand tons per day. The greater number of machines have been used on plants having a capacity of 250 to 450 tons per day. We have found, in a great many cases, with low production at the average sized plant, that the main drawback has been the inability of the road crew to handle the material turned out by the plant. With the application of the finishing machine, the production in several cases has been doubled on account of the ability of the finisher to handle the maximum capacity of the plant, plus a saving in the number of skilled laborers used.

SAVINGS EFFECTED BY FINISHING MACHINES

As an example of the benefits derived from the installation of a finisher after a job was in progress, there is one case in which the average production for nineteen days of hand raking was 1400 sq. yds. per day, against an average production, to the completion of the job in fourteen days, of 2300 sq. yds., through the use of the finisher. Also, the use of the machine eliminated four rakers. The plant in this case had a pug-mill capacity of 800 lbs.

It is possible to lay about 700 sq. yds. per hour on 18-ft. road, and, with an increase in width, the pavement production will increase accordingly, since the machine has a constant forward, or working speed, regardless of width. The saving in labor, therefore, where machine finish is used, is obvious. Only one back-raker is necessary, though where spreader-boxes are not used, as in the case of small plants, the usual number of shovelers must be retained. The use of spreader-boxes will eliminate all but one shoveler, though two men must be used to operate the boxes.

As an example of the saving due to the decrease in labor with the finisher, the following crew was used on one job before and after a finisher was installed:

RESURFACING OLD MACADAM ROAD

Crew used on binder course:

<i>Hand Raking</i>	<i>Machine Finish</i>
1 Foreman	1 Foreman
10 Shovelers	4 Shovelers*
1 Tamper	1 Tamper
1 Truck dumper	1 Truck dumper
4 Rakers	1 Back raker
2 Roller men	2 Roller men
19 Total	10 Total

Crew used on top course:

<i>Hand Raking</i>	<i>Machine Finish</i>
1 Foreman	1 Foreman
10 Shovelers	4 Shovelers*
4 Rakers	1 Back raker
2 Strike-off templet men	1 Steel strip carrier
2 Tampers	1 Truck dumper
1 Truck dumper	1 Machine operator
2 Roller men	2 Roller men
26 Total	11 Total

*In this case the endgate of the trucks was tied and the material partly spread by the trucks.

A contractor operating a small asphalt plant obviously is at a disadvantage, in that he has less chance of realizing the full advantages of machine finish because his crew practically is identical with the crew used by the contractor operating a much larger plant. In either case, however, the finished surface has been greatly improved no matter what the capacity. On the larger capacity plant, with spreader-boxes in use, the contractor not only enjoys a distinct saving in labor, but achieves a saving in the unit costs of labor, due to the greatly increased production of the pavement it is possible to lay. Where a small plant is in use, it is a distinct advantage to haul the material in small trucks, so that the interval between loads will be shorter and the screed member kept at a more uniform warmth. This is true especially on sheet asphalt where the initial compaction under the screed member is about a quarter of an inch, resulting in a surface sealing.

FINISHING MACHINES AND RESURFACING WORK

Plants of 350 or more tons daily capacity involve the use of much larger trucks. In such case, spreader-boxes can be used to a decided advantage if machine finish is used. When plants of small capacity are used, the endgate of the truck can be tied and the material partially spread as the truck dumps. The spreader-boxes eliminate the use of a dumping board and the shovelers necessary to cut the material ahead of the finisher.

The machine, of course, must be run upon forms of strength and contour sufficient to support it. Where a concrete base already is in place, the machine is operated on the edge of the concrete header. On the many successful applications of machine finish to asphalt pavements, many types and sizes of forms have been used. Probably the most popular

wooden forms have been 2 x 8, 2 x 6, or 3 x 6's placed on edge and fastened to wooden stakes. In some cases, where the machine is used to finish both the binder and the top course, a 4 x 4 is used for the binder course, after which a 2 x 4 is spiked to the 4 x 4 to allow for the top course.

Too much emphasis cannot be placed on the need for a careful setting of the forms, because they are the governing factor as to the smoothness of the finished pavement. Where the finisher is operated on concrete headers, the headers should be straight-edged to the required smoothness of the finished pavement.

FINISHING MACHINES ON CITY STREETS

It is recommended that steel strips be placed on wooden forms when a finisher is used to guard against possible damage to the form from the sliding action of the screed member, as well as to bridge any irregularities in the forms themselves. These steel strips can be of suitable thickness to compensate for the roller knockdown, so the finished material will be left sufficiently high, that, when rolled, it will be of exact thickness. Practically all asphalt finishing machines are provided, however, with adjustable endshoes which have considerable vertical adjustment to allow for this compression. This feature also permits easy use of the machine on work below the form tops, such as base courses and leveling-course work, since, through adjustment of these end shoes, the screed member can be operated below the form tops while the end shoes themselves ride upon the top of the form.

Resurfacing work with finishing machines consists mostly of surfacing old macadam, gravel and concrete roads. The first course generally is known as the binder or leveling course, which varies in thickness from one to three inches, depending on the condition of the surface being covered. By lowering the screed member inside of the forms, the leveling course is finished to a true crown and surface. This makes it possible to spread the top course to the same true crown and surface with uniform thickness of material throughout.

On city street work the finisher can be operated on the inside edge of the integral curb and gutter or on the limestone, granite or concrete curb, depending upon the type in use. In the case of the "black base," the finisher can be operated on wood or steel forms, if no permanent curb is in place.

Where there is not a distinct change in crown at an intersection, the finisher lays the center strip and the wings are hand raked. If there is a distinct change in crown, the whole of the intersection is hand raked, either before or after the crown is changed, and the finisher is used only on the straightaway. Where manholes and monuments are in place, no difficulty is encountered in finishing over or around them when the top course is laid, if they are set properly when the base is poured. On the binder course, the screed is raised over the objects and the back-raker easily can rake the width of the manhole or monument.

On streets wider than 30 ft., the asphalt can be laid in two or more strips, depending upon the width of the street. In such case, it is best to insert small steel dowels about 4 in. long, spaced regularly and longitudinally down the base slab. A wooden form is placed over the

dowels and the finisher is run on this form. As an example, a 60-ft. street can be finished in two 30-ft. or three 20-ft. strips. In the case of a street being finished in two 30-ft. strips, one row of steel pins, protruding about 1 in. above the base, should be placed longitudinally along the street. If three 20-ft. strips are used, two rows of pins will be necessary. These dowels should be placed about every 10 ft. One side of the finisher will ride upon the wood form and the other on the completed pavement, protected with a steel angle such as is used on curb work. It has been found that sheet tops less than 1 in. in thickness do not lend themselves to machine finish, because of their tendency to tear under the action of the screed member. This tearing is caused by the sliding, under the screed member, of the material along the base course.

A conclusive example of the saving effected through the use of the finisher is to be found in the case of one state highway department which observed that a saving of 30 cents per square yard in the contract price on sand asphalt roads has been effected since the use of machine finishing became general in that section. Another state reports that the price of asphaltic concrete of 1½-in. thickness on new concrete base similarly has been reduced 17 cents per square yard.

DISCUSSION

CHAIRMAN EMMONS: These papers are now open for discussion. I would like to ask Mr. Donovan if he has had any experience with tension cracks back of the screed on the sheet asphalt? I understand that in California the machine has been used chiefly on asphaltic concrete. This summer I observed many cracks perpendicular to the center line of the road. They seemed to be closing under the roller but they were very noticeable just behind the screed. Does the tearing of the surface on sheet have any detrimental effect on the finished surface, such as cracking after rolling? What do you think is the cause of this tearing?

MR. DONOVAN: The tearing of the surface has no detrimental effect on the finished surface. The screed marks roll out during rolling. We have had no case of cracking caused by the use of a finisher. Tearing is caused by not having sufficient material available to keep the screed warm. On one of our jobs the batch capacity was 1000 lbs., with the trucks hauling six tons. On the road we used spreader-boxes and waited till we had two loads before it was spread. This meant that we used the finisher for about three minutes and waited from fifteen to twenty minutes for the next two loads. During this wait our screed cooled, and when we started again on the next two loads, we had tearing of the surface along the edges on account of the screed cooling. In such cases, if we would use smaller trucks and shovel the material, so doing would cut down the interval between loads and the screed would stay warm.

CHAIRMAN EMMONS: The machine I saw did not have any raking attachment. Are raking attachments standard equipment for these machines?

MR. DONOVAN: No, they are not. They are standard, however, in California on asphaltic concrete, but as yet I have never seen a successful job of raking a sheet asphalt. Personally, I know of no job where sheet asphalt has been raked. We will have trouble in raking sheet asphalt on

account of the material cooling during raking and collecting on the teeth of the mechanical rake, causing an uneven distribution of the material. Rakes are very successful on asphaltic concrete, however.

MR. WILLIAM DAMEWOOD, Chicago, Ill.: In our part of the country, we lay our pavement up until November. I was just wondering what machine could handle our material. We have sometimes quite a long haul of ten or twelve miles, and I was wondering if this machine could handle the material under those circumstances. Many of our people here who live in the North have seen it tear apart.

MR. DONOVAN: We have had that experience, and on a job in Oklahoma we hauled as far as fifteen miles during the month of January. The temperature on the job was as low as fifteen degrees above. Do you ever have to cut the mix out of the truck body?

MR. DAMEWOOD: No.

MR. DONOVAN: In that case, the best thing to do would be to use a rake in the front of the screed. This rake would move transversely with the screed and would break up whatever lumps there would be in the material. Then the material would go down underneath the screed without tearing the surface. That is the only kind of a rake we have used so far on sheet asphalt.

MR. DAMEWOOD: Do you have any trouble with different structures of material on very hard pavements?

MR. DONOVAN: No. If properly mixed it could be hand raked successfully. I believe we could lay it if we had enough material to keep the machine going.

MR. EMMONS: Our next paper is that of "Resurfacing Concrete Roads with Asphalt Wearing Surfaces," by W. H. Sharp, engineer of repairs of the Connecticut State Highway Department.

Resurfacing Concrete Roads with Asphalt Wearing Surfaces

By W. H. Sharp, Hartford, Conn.

Engineer of Repairs, Connecticut State Highway Department

The State of Connecticut has been among the foremost in promoting the improved highway program and has been progressive in adopting the higher types of pavement. The first concrete pavements built by the state were not, as we know them now, laid under ideal conditions. Not enough attention was paid to the condition of the subgrade or drainage conditions, or to the quality of the concrete as far as wet or dry mix is concerned. In the earlier days road administrators had no reliable data upon which to base the probable increase in traffic, and because this increase has far exceeded even the most liberal estimates, concrete pavements that were not designed for the excessive use to which they have been subjected, have required additional care.

The resurfacing of concrete pavements with bituminous wearing sur-

faces primarily is an economic proposition,—that is, to resurface the concrete pavement before it has become so badly broken, or has so deteriorated, as to be valueless for a base. It is difficult to establish any rule as to when concrete pavement should be resurfaced, since there are many things to be taken into consideration, such as the actual condition of the concrete pavement, the cause of that condition, the amount of traffic which that particular highway is carrying, and the possibilities of any future changes in alignments or grades.

FAILURE OF CONCRETE PAVEMENTS

The causes of failure in the concrete pavements in Connecticut that have been resurfaced are poor subgrade conditions, improper drainage, too wet a mix when the concrete was laid, too shallow a depth of pavement and increase of traffic. I think that the last three conditions mentioned are the principal causes of the failures. The majority of the concrete pavements that we have resurfaced with bituminous wearing surfaces during the last seven years were of the so-called wet mix and were 6 in. in depth. In practically all cases the volume of traffic has more than doubled.

It is the intention of the Connecticut Highway Department to resurface the concrete pavement before it has become broken or cracked to the extent that the broken sections are unstable. We have conducted, over a period of years, many experiments as to the various types of premixed bituminous pavements for resurfacing as well as to the various depths at which these bituminous pavements can be laid economically.

For convenience we have classified the premixed bituminous materials to be used in resurfacing work into two general headings: First, semi-rigid pavements, under which heading are classed such premixed bituminous pavements as sheet asphalt, Topeka, Warrenite, etc. Second, flexible pavements, under which heading can be classed such premixed bituminous pavements as Amiesite.

EXPERIMENTS IN SALVAGING CONCRETE ROADS

The condition of the concrete pavement to be resurfaced determines which of the above mentioned classes of premixed bituminous materials shall be used. If the concrete pavement is badly cracked, and especially if the broken sections are unstable, the semi-rigid pavement should not be used, as the movement of the unstable concrete pavement will crack the semi-rigid bituminous surfacing, which, due to its nature, will not heal itself after cracking; whereas the flexible type of premixed bituminous pavement, due to its elasticity, will conform to the movement of the unstable concrete pavement and, eventually, will flush together under heat and traffic.

In 1922 there were laid five experimental sections on the main highway between Hartford and New Haven, Conn., with the following materials: a standard 3-in. sheet asphalt pavement consisting of 1½-in. binder and 1½-in. sheet asphalt top; a 2½-in. Amiesite pavement in two courses, the first course of 1-in. stone and the top of ½-in. stone, a 2-in. Amiesite pavement of 1-in. stone, a 1½-in. Topeka pavement, and a 1-in. sheet asphalt top.

The condition of the concrete pavement when these sections were laid was reasonably good, there being few unstable sections, but the surface more or less deteriorating. The volume of traffic has more than doubled since the bituminous surface was laid. From an inspection of these sections of pavement it is difficult to determine which type of pavement is superior, or that the pavement laid at a depth of 3 in. is wearing any better than the pavement laid 1 in. in depth.

You will note that in this experimental stretch there are three of the so-called semi-rigid pavements of depths from 1 in. to 3 in. and two of the so-called flexible pavements of depths from 2 to 2½ in. We have laid, on various highways, the resurfacing material in depths from ½-in. to the standard 3-in. construction for the semi-rigid type of bituminous pavement and from ½-in. to 2½-in. depth for the flexible type of premixed bituminous pavement. The question of the depth of the resurfacing material is governed primarily by the condition of the concrete pavement and the probable volume and kind of traffic it will be required to carry.

It might be of interest to note that in Connecticut we have one section of concrete pavement laid in 1914 with a very flat grade in which the concrete pavement had not broken but was beginning to scale badly. This section was resurfaced in 1924 with Amiesite at a depth of ½ in., the cost being 38 cents per square yard. This stretch of highway is on our United States Route No. 6, between Hartford, Conn., and Providence, R. I.

STANDARD DEPTH FOR ASPHALT SURFACES

This highway carries heavy concentrated travel of through as well as local traffic, and, due to the presence of a double trolley track, the traffic is concentrated in single lanes. The pavement has stood up remarkably well and has required no maintenance until this last year. We have also tried sheet asphalt top at this same depth of ½ in. but, due to the rigidity of the bituminous material, as well as poor subgrade and water conditions, it did not withstand the traffic wear, and cracked and broke up.

As has already been stated, we have used the so-called semi-rigid bituminous resurfacing material from ½ in. in depth up to 1½ in. in depth for the sheet asphalt top and have experimented with the use of 1-in. binder and 1-in. top to 1½-in. binder and 1½-in. sheet asphalt top.

Through these various experiments we have developed a minimum depth for the semi-rigid bituminous pavements of 1½ in. This should be used only when the concrete pavement is not broken or cracked badly. Otherwise there should be adopted the standard depth of 3 in. for sheet asphalt, or 2½ in. for the other semi-rigid types. On the flexible type the minimum depth is also 1½ in., but in the greater number of cases the standard 2½ in. are preferable.

The cost of this resurfacing work, of necessity, is predetermined by the location of the mixing plant. The average cost, in Connecticut, for a 1½-in. sheet-asphalt-top resurfacing, with an average haul of twenty miles from the plant, is \$1 per square yard, and for the so-called flexible type under the same conditions the average cost is 90 cents per square yard. During the past season we have been experimenting with Colprovia, which is a low penetration asphalt ground very fine and mixed

with a flux oil to obtain the necessary penetration. This, in turn, is mixed with the aggregate for the desired pavement.

Our experiments have covered the following mixes:

BINDER

2.4%—hard asphalt
2.4%—flux oil
32%—three-quarter inch stone
56%—one-half inch stone
7.2%—screenings
The bitumen content was 4.8%.

ASPHALT CONCRETE TOP

3.75%—hard asphalt
3.75%—flux oil
61.5%—one-half inch stone
25%—one-quarter inch stone to dust
6%—limestone filler
The bitumen content was 7.5%.

SHEET COLPROVIA USING TRAP ROCK SCREENINGS

5.5%—hard asphalt
5.5%—flux oil
83.5%—trap rock screenings
5.5%—limestone filler
The bitumen content was 11%.

SHEET COLPROVIA USING SAND

5.75%—hard asphalt
5.75%—flux oil
77.5%—various grades of sand as used in sheet asphalt
11%—limestone filler
The bitumen content was 11.5%.

All of these mixes were laid cold to a depth of 2 in. and as they were laid only during the past season it is too early to determine their value. We also have laid during the past season a section of "Rubber Amiesite," which contains 1 per cent of pure rubber in addition to the usual Amiesite mix.

METHODS OF RESURFACING CONCRETE

In the use of the semi-rigid type of pavement resurfacing, special care must be taken in the raking, and if there is any irregularity in the concrete pavement this should be brought to the grade of the pavement by the use of bituminous material before the top is laid in order to obtain a smooth riding surface, which smooth surface is essential to prevent breaking of the resurfacing material by uneven impact from motor vehicles.

We usually resurface one-half of the highway at a time so as to avoid detours. In so doing it is impossible to obtain the cross rolling which would help to remove a great many irregularities. There is no bond

between the concrete pavement and the semi-rigid type of pavement and this was one of the determining factors for arriving at the minimum depth of $1\frac{1}{2}$ in.

We have tried the "heater method" for applying the semi-rigid type, that is, preheating the concrete pavement to a high degree of temperature and immediately applying liquid asphalt in small quantities before the application of the top. This method was tried on a highway in which were located trolley tracks that necessitated the laying of the bituminous pavement in a very thin layer adjacent to the rails. This was an unusual condition and there were failures, due both to the lack of bond between the concrete and the bituminous pavement and the breaking of the bituminous pavement itself.

LAYING FLEXIBLE PAVEMENTS

The laying of the flexible type of pavement should be in two courses. We have experimented with various sized stone for the first course and we have arrived at the conclusion that the stone to be used in the first course, in size, should be equal to one-half the depth of the pavement,—that is, for a $1\frac{1}{2}$ -in. depth pavement the first course should have $\frac{3}{4}$ -in. stone, and the second course should be of $\frac{1}{2}$ or $\frac{1}{4}$ -in. stone. The depth of the first course should be laid to within $\frac{1}{2}$ in. of the required depth of pavement.

Due to the flexibility of this type of pavement and to the tendency it has of pushing on steep grades we have adopted a standard depth of $2\frac{1}{2}$ in. This type of pavement, having, as it does, a certain amount of free bitumen, makes a very good bond between the concrete pavement and the bituminous material.

The protection of the edges of the pavement, adjacent to the shoulders, can be accomplished by oiling the shoulders. This treatment has many beneficial results. It waterproofs the shoulders and prevents water from following down the edge of the pavement and becoming deposited under the pavement. It also holds the shoulder material in place, and gives more travel area to the highway. In this resurfacing work not only have we attempted to preserve and protect the concrete pavement, but also to give to the traveling public a smooth, comfortable highway to ride over.

CHAIRMAN EMMONS: Further discussion of this subject will be by Mr. George W. Craig, consulting engineer of Chicago, who will present a paper on "The Economic Value of Asphalt Surfacing." Gentlemen, Mr. Craig!

The Economic Value of Asphalt Surfacing

By George W. Craig, Chicago, Ill.

Senior Member of Craig, Skidmore & O'Brien, Consulting Engineers

In discussing the paper by Mr. Sharp there is very little I could say that would add to the importance of the subject of resurfacing concrete. In this short paper I am taking both types of concretes for base, but before I go into that, there is just one thing I noticed that was not touched upon either by Mr. McClure or the other gentleman, and that is what might be said to be a recent development in the preparation of our mixtures for asphalt pavements, particularly sheet asphalt. A great deal of attention has been paid lately to the question of stability and we all recognize that we have made a distinct step forward.

Some engineers, particularly those in the East, have made some studies of what we might call the "dry mix." We hear a great deal about "dry mix" in concrete. "Dry mix" in asphalt, in other words the mixing of the mineral aggregates, forms a portion of the one-minute mixing period. The results that have been obtained in a study of the effect of varying the "dry mix" period clearly show that the determination and use of a definite period of 30 seconds is a distinctive step forward. The mix now shows a much greater uniformity in stability tests. I just wanted to bring that point out. It was brought out last year at the meeting of the asphalt technologists in New Orleans by Mr. Field, and it is an important factor. Greater uniformity can be obtained in our mixtures if we would follow this method. It does not mean a longer time for mixing, nor does it work any hardship on the contractor or the municipality.

FALLACY OF "PERMANENT" ROADS

It is the purpose of the speaker to attempt to show the economic value of surfacing with asphalt. In order that we may consider this subject from an economic viewpoint it will be necessary first to consider in detail some of the fundamentals that go to make up a pavement of useful life. It is recognized at the outset that there is no pavement that will last forever. In using the term "permanent types" of pavement, when comparing them with the so-called "low types," the word "permanent" is used loosely and the term "high type" should be substituted.

Yesterday in our discussion, quite frequently, in comparing the "low type" of pavement to the "high type" as I would say, the expression used was, "the permanent type." There is no such thing as a permanent type. In the archives of the University of Michigan, at Ann Arbor, are some photographs of sections of the Appian Way. You know every once in a while we engineers are confronted with the Roman roads, and we are told what they did and that they are still in existence. Close examination of these photographs discloses great grooves in the stone. Mind you, the stone that went into the Appian Way was a very excellent material of a lava formation, and yet there are grooves in those stones as much as 12 in. in depth, and possibly more. Now, that pavement did not last forever in the sense that it was a permanent and suitable pavement. On

the other hand, we are equally assured, that the asphaltic types stand well in the foreground of the so-called "high type" pavements.

Before entering into the general discussion of asphaltic surfaces, more particularly the economics of such paving, let us discuss briefly portland cement concrete bases, whether new or old, and how they may be constructed. In the construction of a new base we are concerned first as to the subgrade and its suitability for base purposes. To be satisfactory, the base usually is constructed in accordance with specifications that will insure adequate support for the wearing surface. We are aware of the fact that all subgrades are not suitable without preparation. We are also mindful of the fact that certain subgrades are unsuitable for the most rigid types of base construction. For the purpose of this discussion we are content in saying that special cases of questionable subgrade should have special treatment.

IMPORTANCE OF SUBGRADE PREPARATION

A careful study of the findings of those who have given this subject serious thought is extremely interesting and worthy of consideration and intelligent use. The very excellent paper by Mr. Hogentogler this morning is one of many that he has been presenting to meetings of this kind. It clearly shows us the importance of this matter of subgrades. We have with us here in attendance Professor Eno, who has also given this same subject very intensive study.

Portland cement concrete for base purposes usually is constructed by means of the 1-3-6 mixture, or the so-called "lean mix." The use of "lean mix" has been a subject for discussion and much has been written on this subject, notably the discussions by Roy M. Green, consulting engineer and director of the Western Laboratories, Lincoln, Neb., which appear in the proceedings of the Fourth Annual Short Course in Highway Engineering of the Agricultural and Mechanical College of Texas, and in the proceedings of the Sixth Annual Asphalt Paving Conference held in Atlanta, Ga. In these two papers, Mr. Green gives a very complete analysis of the portland cement concrete that is most suitable for base, and the results that can be expected. Uniformly good results are being obtained with the lean concretes, as attested by nearly all of our large cities, and communities generally.

Mr. Sharp pointed out a few minutes ago the work that is being done in Connecticut. The same kind of work is being done in New York. Several hundred miles of road have been resurfaced with asphalt. The same is true of California and of this state, Indiana, and other localities. Here is a most important use for asphalt, since it seems to apply itself most satisfactorily to the surfacing of these bases. Mr. Sharp has shown what might be said to be the accepted time, and if you go beyond that time you are jeopardizing any surfacing material you may use.

Asphalt surfacing is destined to be the dominant method employed in saving the portland cement concrete pavements which are no longer serviceable, by using the old pavements as bases. Some cities, notably Washington, D. C., and Chicago, have constructed some of their portland cement concrete pavements at a lower grade, anticipating that they will be surfaced at a later date. For economic reasons the wisdom of this

method is doubtful and it is believed that this practice will not be general. The slogan, "Eventually, Why Not Now?" might well be applied. The same condition exists as to our country's highways, but on rural highways the salvaging method will be used to a much greater extent. Some authorities, however, are delaying the resurfacing beyond the accepted time, for one reason or another, and in so doing are jeopardizing the possibility of securing the best results.

BASE REINFORCEMENT AND EXPANSION JOINTS

Expansion or contraction joints for base construction are not necessary and, when used, prove a detriment, either by humping the wearing surface or causing unsightly cracks which lead to early destruction. As reinforcing generally is used as a protective measure against expansion and contraction, we are content with saying that, due to the fact that bases are not subject to sudden changes of temperature, it is not necessary to burden the pavement with this additional cost. In the Chicago area we have two outstanding examples of an attempt to use expansion or contraction joints in concrete bases. One of these is in one of our most prominent park areas and the other is in one of the suburbs. In each case, today, there is a distinctive hump or ridge following and immediately over the expansion joint. There are also instances elsewhere that I know of, and that you gentlemen no doubt know of, where this has been done.

There are a number of asphalt wearing surfaces that are suitable for our present day traffic. Here we will discuss sheet asphalt and asphaltic concretes. Sheet asphalt is perhaps the one type that commands our greatest attention, since this particular type is used to a much greater extent than all the others. The design of the sheet asphalt mixture has become better understood. The hit-and-miss method has no place in pavement design. We have much to be grateful for in the work of the asphalt technologists who have given freely of their knowledge and time. Their writings, which have been published in our technical press, are of great value. The studies of the stability of asphalt mixtures that have been made in recent years form a most important contribution to our knowledge. The work of Messrs. Hubbard, Skidmore and others, on stability, are notable contributions to asphalt technology. These same remarks equally are true as to the asphaltic concretes and the special cold asphalt cements.

MAINTENANCE OF ASPHALT PAVEMENTS

Consideration of volume, speed and weight of traffic is fundamental in designing asphalt pavements. We feel confident that we are now designing and laying asphalt pavements that fully will meet the requirements of the traffic and climatic conditions. Frequently we hear statements as to the high cost of the equipment necessary properly to maintain asphalt pavements, and also the high cost of the maintenance itself. We have been privileged, however, to compile and record a large amount of reliable data from which we can predetermine what reasonably can be expected in the way of maintenance costs.

George W. Tillson, the dean of municipal engineering in this country, in commenting on a paper by R. H. Simpson, chief engineer of the De-

partment of Public Service in Columbus, Ohio, entitled "Repair Costs of City Pavements," as read before the American Society for Municipal Improvements at its thirty-first annual convention, said:

"I do not think a paper of this kind presented to this society should be passed without being very highly commended. Anyone who has studied the costs, over a series of years, of any kind of pavement, trying to compare the costs of those repairs with not only the different kinds of material, but the cost of different streets, knows how great and how many problems arise in trying to make this comparison. And I do not think I have ever read a paper, or seen a subject presented that showed a more thorough knowledge of the subject and the difficulties and problems, and as good a solution as has been shown in this presentation today. I am not surprised at the City of Columbus having such reports, because I know that their repair costs have been kept in good condition for a good many years."

This quoting of Mr. Tillson at length is for the purpose of showing the thoroughness and care exercised by the City of Columbus in securing the data presented below. Using the data contained in that paper by Mr. Simpson, showing the cost of maintenance for all asphalt pavements within the City of Columbus, we find that the average cost of maintenance, per square yard, for the first ten years, is \$.005 per year; for 15 years, \$.008 per year; for 20 years, \$.02 per year; for 25 years, \$.03 per year; for 30 years, \$.035 per year, and for 35 years, \$.04 per year. Mr. Simpson shows that on streets of heavy traffic, especially street railway streets, the cost is slightly higher.

MAINTENANCE COSTS IN LOS ANGELES AND HARTFORD

The Los Angeles, Calif., cost accounting department shows that the average cost of maintenance of sheet asphalt in Los Angeles for the years 1913 to 1924, was \$.0143 per square yard, per year, with asphaltic concrete just under \$.01 per year for the same period. The City of Washington, D. C., reports in 1927 an average cost of \$.0276 per square yard for all asphalt streets, some of which were 40 years old and the average life of all pavements being 30 years. Hartford, Conn., reports that the annual cost per square yard has not exceeded \$.02. These figures, from widely scattered cities, indicate that the maintenance cost of asphalt pavements is relatively small, compared to certain other types, and they should assist us very materially in determining the real merits of asphalt.

We are all more or less familiar with the cost of the equipment necessary for making repairs, and it is needless to say that large and expensive equipment is unnecessary, except in the larger centers where large yardages and paving plants exist. Many types of equipment, ranging in price from \$300 to, perhaps, \$6,000, are being used successfully. The use of cold-mix asphalts is proving quite effectual, since they can be used with even less expensive equipment. The \$30,000 plant, as advocated by those who are misinformed, need not be discussed, except to say in jest that mother's dishpan, a stolen contractor's shovel and a pair of willing hands sometimes will suffice for making repairs.

Asphalt, as a medium for surfacing portland cement concrete, is well understood. Likewise its life as a wearing surface. The adaptability of this material will here be touched on briefly.

CONCRETE BASES FOR ASPHALT SURFACES

From the early conception of asphalt pavements, the type has met with the ardent support of the municipal engineer. The widely extended use of asphalt can be attributed to its lasting qualities, its pleasing appearance, its economic values, its ease of replacement, the added protection to the base that it affords by its exclusion of surface moisture, and its ability as a surface to absorb impact. Due to these qualities bases can be used for what seems an almost indefinite period, and adding a new surface is much the same as purchasing half-soles for a good pair of shoes.

The life of asphalt surfaces, to a great extent, is dependent upon the climatic and traffic conditions. Some cities have attempted to establish what might be termed a useful life. Generally, this life is placed between 20 and 35 years. Many city street departments point with pride to certain asphalt streets coming under their observation that have a much longer useful life. At the expiration of this useful life the base again is used for a new surface, thus extending the life of the base for an indefinite period. Widening, alteration and repairs, either to base or top, also are accomplished at a minimum expense and with the most pleasing and lasting results.

RESURFACING WITH "BLACK BASE"

Resurfacing of other types of foundation must not be overlooked. There is a very large field in this respect which is being taken advantage of, including "black base," one of the oldest base types and one that is being used in almost every state of the Union and province in Canada. Well compacted and stabilized macadams are surfaced with asphalt without hesitancy. Thoroughly constructed gravel roads and streets, too, are being surfaced with asphaltic mixtures, in most cases by using binder or "black base" as an intermediate course. Resurfacing with asphalt, as a means of prolonging the life of all useful bases, is unlimited in its possibilities when constructed conservatively and intelligently.

Since we have touched upon some of the details and possibilities of construction, now let us consider the aesthetic qualities and comfort afforded the motoring public by asphalt surfaces. Their aesthetic value is well recognized, in that asphaltic surfaces are of the best appearance and harmonize with the surroundings whether they be in the business district, or the residential or rural sections. Their noiselessness is appreciated, since quiet and comfort are necessary in our daily life.

ECONOMY OF INITIAL ASPHALT SURFACING

Real economy is to be found primarily in the long life of the well designed and constructed asphalt pavement in the first instance, and in the use of the old base for resurfacing in the second instance, thus extending the useful life of a pavement for a much longer period of time. It is not uncommon, in considering the cost of the present standard

types of pavements, to find asphalt and portland cement concrete close competitors. Usually, portland cement concrete is the lowest in first cost, and when first cost only is considered it may be selected without regard to the useful life of asphalt. However, first cost is merely one element in the ultimate cost of a pavement.

Ultimate cost must be considered in conjunction with the economic life of the pavement in order to ascertain the total cost burden. The basis of computing ultimate cost is the writing off, in equal annual installments, of principal and interest, at, say 5 per cent, during the economic life of the improvement. The average annual cost having been obtained, the ultimate cost can be computed for any desired period. As the various component parts of a pavement, such as base and wearing course, etc., differ in the duration of their economic life, the ultimate cost of the whole pavement is found by the summation of the ultimate costs of these individual component parts.

INITIAL AND ULTIMATE COST

As an example, let us assume a 7-in. reinforced concrete pavement whose initial cost is \$2.60 per square yard to have an economic life of 15 years. Assume, also, this same pavement to be used as a base for an asphalt top at the end of 10 years. Assume, likewise, a 3-in. sheet asphalt top, whose initial cost is \$1.55 per square yard, to have an economic life of 20 years. Assume, then, a 6-in., 1:3:6, concrete base whose initial cost is \$1.50, and whose economic life is 40 years. Using a standard annuity table we obtain the following:

Ultimate Cost at End of Forty Years

Type	First Cost	Int. Rate	Yrs.' Life	Annual Cost per Sq. Yd.	Total Years in Use	Ult. Cost per Sq. Yd.
Reinforced concrete as a pavement	\$2.60	5%	15	\$0.25	40	\$10.00
Reinforced concrete as a base after 10 yrs.....	2.60	5%	40	0.152	40	6.08
Asphalt surface on old concrete after 10 yrs.	1.55	5%	20	0.124	30	3.72
Total						\$9.80
Asphalt surface at outset	1.55	5%	20	0.124	40	4.96
Concrete base at outset.	1.50	5%	40	0.087	40	3.48
Total						\$8.44

From the above figures it will be seen that, while the asphalt pavement on the concrete base cost, initially, \$3.05, or 45 cents more, per square yard than the portland cement concrete pavement, when first cost only was considered, yet, the same pavement showed an ultimate saving of \$1.56 per square yard over a period of 40 years. Further, the asphalt pavement, built originally as such, showed a saving of \$1.36 per square yard over the resurfaced pavement at the end of the same period of time. Thus we see that ultimate cost is a most important factor and must be considered in relation to the economic value of asphalt surfaces, especially as applied to the resurfacing of existing portland cement concrete pavements.

CHAIRMAN EMMONS: The hour is getting late and we have one more paper. Therefore I will ask for the paper entitled "Rough Texture Asphalt Pavements in Europe," by Mr. F. J. Leduc, chief of the Municipal Materials Testing Laboratory, Montreal, Quebec.

Rough Texture Asphalt Pavements in Europe

By F. J. Leduc, Montreal, Que., Canada

Chief, Montreal Municipal Laboratory for Testing Materials

This is rather a pretentious title for the paper I have the honor to present. It is not at present in the mind of the author to cover the whole field disclosed by this title, but rather to report notes taken while traveling through the European Continent last fall and early winter. It is hard for a stranger to describe fully the phenomena observed. Lack of time and inadequate knowledge of the customs of the country often lead to erratic judgments but at the same time, the observer, at the risk of erring in his deductions, must transpose into his own national units the observations made. With this reservation in mind, I will describe some of the pavements inspected, mentioning the points which seem to me most interesting.

CONSTRUCTION METHODS INTERNATIONAL

Safety and smoothness of travel, combined with economical construction and upkeep, are the principal aims of the road builder. Methods of construction and equipment used are so internationalized now that very little difference exists between here and over there. However, we cannot treat alike all theories justifying such and such a type of pavement. Different ways of thinking, due to a different education and a different medium, and conflicting interests and prejudices, as well as the simple act of wanting to produce something different, are the causes of different theories. Why, for example, do many European engineers prefer the asphalt mastic, called "Asphalt Coulé," a derivative of the old "stamped" or tamped-in-place European rock asphalt, to ordinary standard hot-mix, even after the ease of handling and the cheapness, stability and safety of the latter type have been fully demonstrated? Undoubtedly the fact that the capital invested had to survive has led to the production and development of these new theories and practices in the old field.

Before describing in detail the different types of European rough texture pavement I will take the liberty of giving some general observations. The desirability of a roughened surface is admitted. It tends to reduce to a minimum the risk of driving on our modern roads. It does not, however, exclude all perils, because the surface of the road itself is but one of the many factors governing the safe driving of a vehicle. Such importance has been attributed to skidding of cars on road surfaces, in the determination of the fitness of certain types of pavement, that it might be interesting here to give, in free translation, a brief definition of skidding, found in Le Gavrian's book, "Chaussées Modernes," and in doing so, to determine a few of the many factors connected with it.

We say that a vehicle skids when it is suddenly deviated from its trajectory. Skidding may be produced by the effect of a shock, or it may happen without the presence of this cause. In the first case, take skidding produced by the effect of a shock. It is generally the front wheels that receive a percussion, due to the presence of an obstacle, and the vehicle takes an oblique direction to its normal movement. By virtue of inertia the rear wheels try to continue their natural course, but the front wheels being blocked, the rear wheels tend to pivot around. In the second case, the same phenomenon may be produced without the intermedium of a shock. This is the case, for example, when the car travels on a slippery surface. Of course, both causes may combine and produce skidding. That occurs in the case of a too sudden application of the brakes or because of an unbalanced set of brakes.

VALUE OF EXPERT DRIVERS

Now that a definition has been given to skidding, we may mention certain causes that tend to produce it. To lead the list, no better factor could be named than the simple act of driving. A good chauffeur may travel without any risk on surfaces where a poor or indifferent one will break everything. To illustrate this, let me cite the experience of the London General Omnibus Co. This company, operating thousands of buses in and around London on streets with the densest and heaviest traffic in the world, has built a circular training track where its employees are given special driving lessons, and upon which they pass their final driving tests before taking charge of the buses. This track is at least 200 feet in diameter and is lubricated with the best products obtainable for the special purpose in mind—grease, oil, soap, fine dust, soot, etc.—so as to duplicate the worst imaginable driving conditions. It is on a plane exposed to all the wind that blows.

Though the employe receives special instructions in the way he should handle his car, at his first trials the observer may think that the candidate is trying to accompany the music of some distant Viennese waltz. His bus keeps whirling and whirling around all the time. As he gains more experience and follows better and better the instructions given, his car steadies down till he can pass it between parallel obstacles placed in such a way as to give but a few inches of clearance. The ability to do so qualifies him as a chauffeur. If this man leaves his work for more than a fortnight, through sickness or a furlough, or for any other reason, he is sent back to the track to pass this same driving test before resuming his daily occupation.

CAUSES OF SKIDDING OUTLINED

This training has been referred to at length just to show that there is a lot to be gained through the proper education of drivers. Less would be heard about the slipperiness of roads if the proper training were given, and examination made compulsory for those using our roads. It might be interesting to note, too, that in 1928 there was held in Besançon, France, a road congress, where remarkable papers were presented on the different apparatus tending to make roads safer. Changes in the surface of the road were advocated so as to make driving emergencies less frequent.

As a further cause of skidding, we may mention the state of the layer of foreign matter between the wheels of the vehicle and the road. The engineer may control the contribution of the road itself to the formation of this layer, but he does not control the other materials brought on to it from exterior sources. The atmospheric agents, as well as the automobile itself, are good carriers of materials that help to form this layer, the ultimate composition of which may comprise anything possible, including soot from the burning of soft coal, industrial dust, oil, grease, water, ice, etc. All these elements combine to produce a very efficient lubricant, and in some places, during the winter, the formation of such a layer is constant and lasts for days. The road engineer has to face the two already mentioned causes but by the proper design of his pavement he tries to minimize their effects. Some types of wearing surface designed to that effect will now be described.

The practice of using seal coats on bituminous macadam seems to be general in Europe, and the life of such a coat averages three years. A bituminous compound is sprayed on the surface and covered with stone chips. Near London, owing to special conditions, the material examined was a hard, well screened gravel. The amount of it on the road exceeded that generally carried here. Even after being submitted to traffic for a few weeks the gravel kept its natural color. Although in excess, it adheres well to the road, does not form pot holes and gives a smooth driving surface, though rough in appearance.

ROUGH SURFACE SEAL COATS

On wood-block pavement, a seal coat also is used. Gravel is spread on it in such an amount as to form a bituminous mat. This gravel roughens the surface and, at the same time, enters between the fibers of the block, compressing them on the joint and sealing it, and in so doing, holds it water tight. It is not an unusual sight in big European cities in the winter to see large piles of gravel or grit on the sidewalks. These constitute the supplies from which road keepers draw once in a while to roughen the surface of their thoroughfares.

Sheet asphalt is used, but a preference now is given to stone-filled sheet asphalt, in which 15 to 25 per cent of stone passing $\frac{1}{2}$ inch mesh is added to the ordinary standard mix. One of the reasons for this practice is to offer to the wheels a rougher surface. With a view to providing a roughened surface on ordinary sheet asphalt, after initial compression, and while it is still warm and in a plastic condition, it is covered with a layer of clean, hard, $\frac{3}{8}$ -inch cubical chippings, which have been coated previously with approximately 2 per cent to 3 per cent of asphaltic bitumen of medium penetration.

A third method of providing the roughened condition exists in Zurich, Switzerland, where it was examined by the author. Although applied to a stone-filled sheet asphalt containing from 15 to 25 per cent of stone, I was informed that the same thing applied to the standard sheet asphalt. Since new street practice is being developed with this system, it might be of interest to describe it more fully. The supporters of this system claim that the practice of rolling a mixture when it is hot and very plastic is wrong. They hold that compression is not properly

applied by a roller. To be right, it should be exerted vertically from the bottom up, and since at present it is impossible to do this, it should at least be from the top down.

TAMPED ASPHALT AND STABILITY

Compression with heavy rollers in the ordinary way is not a clean, vertical one, being accompanied by a longitudinal push, which action forces the material up against the places where it encounters the most resistance. It accumulates there immediately, creating centers of further disturbances, although when the work is finished this is not apparent to the eye. Traffic simply will exaggerate those defects and the pavement, although in many cases it will not become wavy, will at least have a very poor appearance, because of shadow marks. Eventually, too, the pavement will become glossy.

To back their contentions, the European engineers have to guide them, their wide experience attained in handling stamped asphalt, this type of pavement having produced remarkable examples of stability. So to achieve their ends, they resort to a somewhat different street practice than ours. Their system is as follows: The road is leveled to the proper profile, and the hot wearing coat is raked well into place and allowed to cool. In very warm weather this period may be from between 40 and 50 minutes, and in the late fall, when the thermometer reads around 40°, it may be from 15 to 20 minutes. Then the surface is ready to be rolled.

First a hand roller weighing around 500 pounds is passed 10 to 12 times in a direction perpendicular to the axis of the road. This first rolling is followed by a second one with a steam roller weighing from one to one and one-half tons. It is directed in the same way as the hand rolling and for the same number of times. Finally, a cross-rolling by a 10 to 15-ton tandem roller is continued until the surface becomes cold. Traffic completes the compression of the pavement. Enough initial compression is given by the above procedure to make the pavement water-proof. One result of this practice is to produce a roughened surface without sacrificing the evenness of the profile. Another result is the practical disappearance of the wavy effect noted when traveling at night or in wet weather. It is claimed that this will last for years.

ROCK ASPHALT CONSTRUCTION IN EUROPE

Other contentions are made in favor of this practice, as, for example, the increase in stability, but this part is not within the scope of this paper, and therefore is omitted. The above description is given only to indicate that a more extensive study could be made of this practice, and that departure from present American practice possibly could be made with benefit to our asphalt pavements.

It would be improper to speak about European practice without mentioning roads made with the European rock asphalt. The original "stamped" asphalt has not survived, for, though it had certain decided advantages at its inception, it is now an obsolete type. It may surprise our engineers to learn that it survives only as a binder course or, possibly

I should say, a cushion coat. The main objection to the "stamped" asphalt was its slipperiness, which could not be denied, but this gave rise on the Continent to a new type of asphalt mastic pavement called, even in England, "Asphalt Coulé." Elaborate specifications have been developed to cover the construction of this type, and I know of none better than the one from "Direction Administrative des Travaux," Ville de Paris, 15 Avril, 1915.

COMPACTION BY TAMPING

The "stamped" asphalt was produced first by pulverizing the natural rock meeting certain specifications, heating this product in kettles to 275° F., and raking this mass on the street and tamping it, while still hot and compressible. To produce "Asphalt Coulé" it is necessary first to produce at the mine a uniform product, and blocks weighing around 100 pounds are cast. They are made by heating the pulverized matter and added bitumen, so that the blocks will have a final content of around 15 per cent of bitumen. These blocks are shipped to the different contractors, who make the final preparation in kettles provided with mechanical agitators. An example of a formula used will best illustrate the procedure, so here is a typical formula for street work:

Prepared rock asphalt mastic.....	100 kgs.	59.17%
Added asphalt	4 "	2.37%
Added stone	65 "	38.46%
	169 "	100.00%

This will give a final bitumen content of around 11.3 per cent.

The rock asphalt blocks and the asphalt are first introduced into the kettle and when these are melted together the hot stone is added. The heating operation lasts approximately seven hours. The product then is loaded in locomobiles provided with mechanical agitators and sent in them to the streets, where the material is floated into place and left to cool without any further compression. To increase the anti-skid property of the pavement, steel bars $\frac{1}{2}$ of an inch thick are placed in V formation, spaced about every 5 inches, where they are left for a while. When taken out, they leave ridges about $\frac{1}{4}$ of an inch deep. Those ridges were originally expected to last 3 years, but it is now evident that they will last for a much longer period.

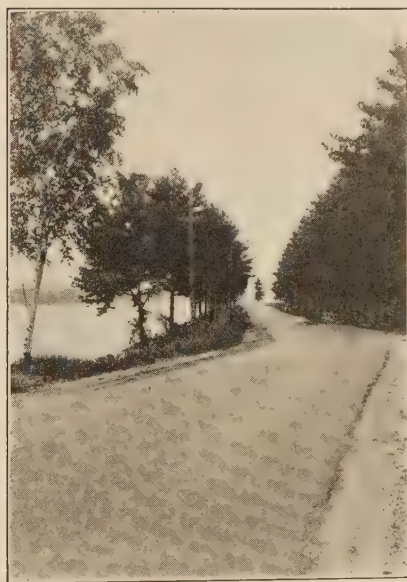
USE OF INDENTED HAND ROLLERS

Another system for increasing the anti-skid property is the passing of an indented hand roller on the surface, leaving holes in the pavement. Such holes have lasted for more than four years on a medium traffic street. This type of pavement has a natural stability that keeps the mixture from flowing to fill the indentations in its surface.

We cannot close this rapid survey of European roughened surfaces without mentioning the fact that a type of pavement has been produced in Europe in the last five years based on a new conception of the

function of the asphalt cement in a paving mixture. In this case the asphalt is no longer considered as a binding material, but as a lubricant. Enough asphalt coats the aggregate, which, of course, is a fine, well graded one, to exclude moisture and facilitate its movement in the mass. It is only lightly rolled and in many cases only tamped. The traffic gives to the material its final compression.

It is a very stable pavement, unaffected by the atmospheric agents, and the surface is even but with a rough texture. Unfortunately the author of this paper had not the time to make a complete study of this type, but it looked to him very promising. A complete investigation of it might be of great interest to the asphalt technologists, as it indicates drastic departures from ordinary conceptions.



FIFTH SESSION

OCTOBER 31, 1929. 10 O'CLOCK A. M.

MAJOR FRANK M. KENNEDY, CHIEF, BUILDINGS AND GROUNDS
DIVISION, OFFICE, CHIEF OF AIR CORPS, U. S. ARMY, WAR
DEPARTMENT, WASHINGTON, D. C., PRESIDING

CHAIRMAN F. M. KENNEDY: We will have for the subject under discussion this morning, the question of airport paving. This should be of unusual interest to all of you gentlemen who are connected with asphalt and the paving industry, for the reason that it presents so many interesting technical problems. It is a subject that, in its future, has possibilities for an enormous amount of business that should interest every one. To start the discussion this morning, we have a paper entitled "Standard Paving for Airports," by Mr. R. H. Simpson, chief engineer, Department of Public Service, Columbus, Ohio.

Standard Paving for Airports

By R. H. Simpson, Columbus, O.

Chief Engineer, Department of Public Service, City of Columbus

The development of air transportation in the United States during the past two years is the outstanding achievement in this country for this period. The advance in this industry is almost unbelievable. Almost overnight millions of people have become interested in aviation. We have become an air-minded nation. Almost every community has acquired land for an airport or is making an effort to do so. Most of the so-called airports that have been established, however, are nothing but landing fields, being unimproved tracts of ground and having wind indicators and perhaps hangars and beacons.

IMPORTANCE OF USABLE ALL-YEAR RUNWAYS

I visited an airport, this fall—at least it was advertised as such—that consisted of about one hundred acres of ground with a pole erected on one side of the field, to which was fastened a wind indicator. There was considerable interest in the one small plane operating on this field and many people were attracted there. The field seemed to meet the present needs of the community, but it was the first step in the development of an airport.

Many ports in our larger cities were started in this way, and at some of them the field is still in such a condition that it cannot be used at certain times of the year, especially by the heavier transport ships which are coming into more general use. Most of these fields are badly in need of take-off and landing areas that can be used under adverse weather conditions. It is the purpose of this paper to bring to your attention



LAYING ASPHALTIC CONCRETE SURFACE ON RUNWAYS AT PORT COLUMBUS AIRPORT, COLUMBUS, OHIO, IN JUNE, 1929. SPREADING THE HOT MIX

the need of paved areas at airports and to indicate a standard type suitable for this purpose.

A prominent government official is quoted as saying, recently, that the crying need of aviation today, in the United States, is one hundred properly equipped airports located at strategic points. There is no doubt of such a need. But I would go further and say that the greatest need of air transportation today, is paved take-off and landing areas at our airports. We must equip our airports so they can be used for twenty-four hours in the day and three hundred sixty-five days in the year. With transport ships flying on schedule and more such scheduled air lines being established monthly, we have reached a point where the delay to the departure of ships, or the inability to land because of a muddy field, is intolerable.

MOST CITIES WILL NEED PAVED AIRPORTS

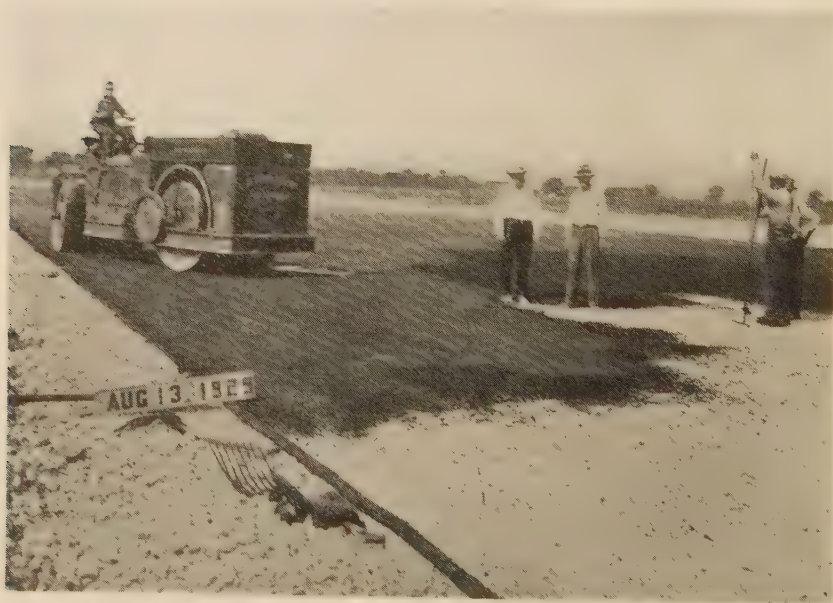
It is recognized that in some parts of the United States, such as the arid sections of the West, with sandy soil, paved runways may never be required. An oil treatment will give a firm and dustless surface. There are also locations underlaid with gravel, that, no doubt, can be treated with asphaltic oils at nominal expense to produce a satisfactory surface. But the greater percentage of airport sites will require paved runways, if dusty and muddy fields are to be avoided. I believe that the condition of the runways is now a deciding factor in determining the suitability of a field for the safe operation of a given plane.

Let us consider for a moment the character of traffic to which runways are subjected. Some articles have appeared in print during the

year, in which it was argued that the pavement for runways should be designed on the same basis as our highways, because the traffic on both is similar. I can see very little similarity in the use of airport runways and that of the highways. The paved portions of the runways are five or six times as wide as a highway, and a plane may take off or land on any portion of this width. If one observes a number of planes taking off, one after the other, he will notice that no two of them use the same path. On a highway the traffic is confined to narrow lanes, and a series of cars will follow each other in the same narrow lane. There is no opportunity for congestion on a runway, for only one plane can use it at a time. On the other hand it is well known how badly congested most of our highways are at times.

AIRPORT TRAFFIC LIGHTER THAN ON HIGHWAYS

Then again, the highway may be subjected to the impact of heavy, fast moving trucks, all moving along the same narrow lane of traffic. A plane will move along, in landing or in taking off, any part of the runway, and the impact is comparatively small, because of the shock absorbers on all heavy planes, and from the fact that the wings carry part of the load, depending on the speed. There is no question, therefore, but that the traffic on airport runways is very much less than on the highways, and that it is spread out over a much wider area. I am convinced that the effect of impact from landing and departing planes is not as great as is commonly believed, although there is a lack of data on this subject. It follows, therefore, that with much less vehicular move-



LAYING ASPHALTIC CONCRETE SURFACE ON RUNWAYS AT PORT COLUMBUS AIRPORT, COLUMBUS, OHIO. ROLLING OPERATIONS



ASPHALTIC CONCRETE SURFACE USED ON RUNWAYS AT PORT COLUMBUS AIRPORT, COLUMBUS, OHIO. SHOWING THE SURFACE TEXTURE

ment, spread out over a much greater width, the pavement for runways does not require the same design as that for a road.

Now let us consider the requirements for runway pavement: (1) It should be one that can be built at reasonable cost. (2) It should have a well drained sub-base. (3) It should have a base to distribute the load. (4) It should have no abrupt change in grade. (5) It should have an even, true surface. (6) It should have a roughened or non-skid surface texture. (7) It should have a waterproof surface. (8) It should have a slope to carry off the water. (9) It should have a dustless surface. (10) It should have good visibility from the air. (11) It should have a surface easily and quickly repaired without delay to its use.

ASPHALTIC TYPES MEET NEEDS

There may be other desirable conditions that may occur to some, but any pavement that will meet the requirements outlined, in my opinion, will make a satisfactory pavement for runways. It will be seen, at once, that an asphaltic type of surface will meet these conditions as to surface. The type of base will depend largely on the character of the soil and the condition of the sub-base on which it is laid. If the soil is easily and readily drained, a crushed stone or waterbound macadam base may be satisfactory. On many soils an asphaltic concrete base may be the answer. If the drainage conditions are bad or uncertain, it may be best to use portland cement concrete for the base. Asphaltic concrete, or "black base," has been used very successfully at a number of airports and will be found satisfactory under many conditions.

The asphaltic concrete surface, if properly designed, will, I believe, produce the most satisfactory surface that can be constructed, regardless of the base used. It has a resilience not found in other types of hard surface pavements and its ability to withstand impact, without damage, is well known. It is economical to construct and can be laid quickly and put into service almost immediately. If light repairs are needed they can be made with scarcely any interruption in the use of the pavement. If a general surface treatment is required the work can be done with a minimum of interference in the use of the field. An asphalt surfaced runway can be given any surface texture desired, from smooth sheet asphalt to a roughened asphaltic concrete. Another favorable characteristic of the asphalt surface is that it is dustless. The propellers of a plane when revolving will stir up clouds of dust from most any other type of pavement, but this is not noticeable at all on an asphalt surface.

BASE CONSTRUCTION AT PORT COLUMBUS

In connection with the construction of the municipal airport at Columbus, Ohio, it was decided, after careful consideration, to construct the runways and the taxi-way connecting same, with asphaltic concrete laid on a portland cement concrete base. This pavement has been in service for only about three months, but it has been commented upon very favorably by all who have had occasion to use the field. In the construction of this pavement, it was our plan to obtain a roughened non-skid surface, and the exact mixture was decided upon after experimenting with different percentages of materials. It is felt that this



PAVED LOADING PLATFORM FOR AIRPLANES AT PORT COLUMBUS AIRPORT, COLUMBUS, OHIO. ADMINISTRATION BUILDING AND PASSENGER STATION IN THE DISTANCE



LANDING FIELD AT PORT COLUMBUS AIRPORT AS SEEN FROM ROOF OF ADMINISTRATION BUILDING. PLANES STANDING AT THE EDGE OF PAVED AREAS

construction has resulted in a high-type pavement at a moderate cost. A description of it will be of value to all those interested in airport construction.

Two paved runways have been constructed at Port Columbus, one in the direction of the prevailing winds and the other in the direction of the high velocity winds. The former is 3500 ft. and the latter 2500 ft. in length. Both are 100 ft. in width. *There is a circle 200 ft. in diameter at the ends* to enable planes to turn easily. These runways cross at a point about 2000 ft. from their eastern end. A pavement 30 ft. in width connects the eastern ends of the runways. The hangars face this pavement and are connected to it with concrete aprons. In a longitudinal direction the runways were laid to a grade that fits the ground as closely as possible. This grade is very flat and surface drainage is secured by a cross slope of 6 in. in the width of the 100 ft. The water is caught in a gravel filled trench at the edge of the runway and is carried away through a tile drain laid at the bottom.

DESIGN FOR THE RUNWAY

The design for the paving of both the runways and the taxiway called for a 1½ in. asphalt surface laid on a 5-in. concrete base and was based on the assumption that the subgrade would carry the load. This required, of course, a dry and stable sub-base. In addition to the drain at the edges of the runways three lines of tile were laid under the pavement and connected to the main drains at frequent intervals. The soil was rolled and, where soft spots were encountered, the material was removed and the spaces filled with coarse limestone, which was compacted by heavy tractors and finally by a roller.

The concrete base was constructed under our standard specifications for pavement bases. It was mixed in the proportion of one part of cement to eight of aggregate and is 5 in. thick. The top surface was finished rough so as to furnish a mechanical bond for the asphalt surface. Expansion joints every 400 ft. were provided in the concrete base. These were 8 in. wide and filled with asphaltic concrete, compacted by tamping.

ASPHALT SURFACE AT PORT COLUMBUS

The asphalt surface consists of a mixture of bitumen and mineral matter in accordance with the following specifications:

	Per Cent
Bitumen	5 to 6
Mineral matter passing 200 mesh screen.....	5 to 6
Mineral matter passing 80 mesh screen.....	8 to 10
Mineral matter passing 40 mesh screen.....	12 to 15
Mineral matter passing 10 mesh screen.....	8 to 10
Mineral matter passing $\frac{3}{4}$ in. screen.....	55 to 65
The mixture as laid averaged as follows:	

	Per Cent
Bitumen	6
Mineral dust	6
Sand	28
Stone	60

This was found to give the result desired, which was a dense mix, but with a roughened surface texture.

The bitumen used was asphalt refined from Mexican oils. The 200-mesh material was limestone dust from local quarries. The 80, 40 and 10-mesh material was Lake Erie sand and the coarse aggregate was $\frac{3}{4}$ -in. crushed limestone from local quarries. The material was heated and mixed at a standard plant, under standard specifications and hauled to the site in trucks. It was raked and spread in the usual manner and rolled with 10-ton tandem rollers.

It may be of interest to know that the contractor laid the asphaltic concrete surface, amounting to 90,200 sq. yd., in thirteen working days, an average of 7000 sq. yds. per day. The maximum laid in one day was 9600 sq. yds. The haul was about nine miles and eighteen trucks were used to haul the mixture to the job. Due to very strong competitive bidding the pavement cost only \$1.25 per sq. yd. It was estimated at \$1.75 per sq. yd., and it should be laid for this amount in most all localities.

EXPANSION JOINTS IN THE BASE

Now, I have a few slides I would like to present, the first of which is a photograph of a model of the Columbus airport before any work was started. The field is somewhat rectangular. This broad white line represents a highway to be built some time in the future. Here are the runways. The hangars are located along this taxiway. There is a road up here and another down here. The boundary lights are represented by small dots. The next slide is a picture of the municipal hangar which is just being finished. This type of hangar is used on the fields exclusively. The city has control of the architecture as well

as the location of these hangars. The next slide is a view showing the concrete surface with the expansion joints partly filled with asphaltic material. As a rule we do not use expansion joints in our concrete bases, but this area was so large that we put in a rather liberal joint and filled it with the same asphaltic material used on the surface. The next slide is a view of the asphalt being dumped from trucks and raked. This also shows the drain at the side, the last 8 in. being filled with crushed limestone, which forms a light boundary around the field and



PORT COLUMBUS AIRPORT AT COLUMBUS, OHIO, AS SEEN FROM THE AIR. VIEW SHOWS ASPHALTIC CONCRETE RUNWAYS

aids in the visibility of the runway. The next slide is a picture of the rolling of the asphalt surface. A rope is used along the edge to give us a fairly straight edge. This slide also shows the large limestone filling the trench at the side. Here is a picture showing the surface texture. Unfortunately I have no scale here. The stone looks larger than it really is. It is a $\frac{3}{4}$ -in. stone. We have really a very dense mix, 28 per cent sand.

This is a view of the loading platform for the transport planes, with

the station and administration buildings here. The lower floor of this building has a waiting-room for passengers and a restaurant. The upper floor is used for offices by the transport company and the field manager has an office in this part. The beacon is on top. The controls for lighting the field are in the tower. We can get an idea of the texture of the asphalt surface from this photograph also. That platform is about 200 ft. wide and 300 ft. the other way. This slide is a view of the field from the top of that building you saw in the last picture. The loading platform is here. The hangars are off of the picture here. That is the taxiway, right here, connecting with the hangars. This field is all leveled down and is now covered with grass. The port will all be grassed eventually.

Here is an air view of the field taken about six weeks ago. This is the eastern end. The Pennsylvania Railroad is here. The passenger station is at that point. The passengers walk from the passenger station into the administration building, located there, thence to the loading platform. This is the T. A. T. hangar. That is the Curtiss hangar, and the municipal hangar is under construction. The short runway is in a northwestern direction. The long runway is in a southwestern direction. These lines you see here show the location of the tile used for the sub-drainage. It may be of interest to you to know that we used about 32 miles of sub-drains in trying to drain this field, the outlet being into a stream at this point.

CHAIRMAN KENNEDY: I am sure Mr. Simpson would be very glad to answer any questions that anyone may desire to ask him. I might say, for the benefit of those inclined to leave, that we hope to complete this session about twelve o'clock. The next paper we have this morning is entitled "Experimental Runway Construction at the St. Louis Municipal Airport," by Mr. Mark R. Thompson, engineer in charge of bituminous pavements, Board of Public Service, St. Louis, Mo.

Experimental Runway Construction at the St. Louis Municipal Airport

By Mark R. Thompson, St. Louis, Mo.

*Engineer In Charge of Bituminous Pavements, Board of Public Service,
City of St. Louis*

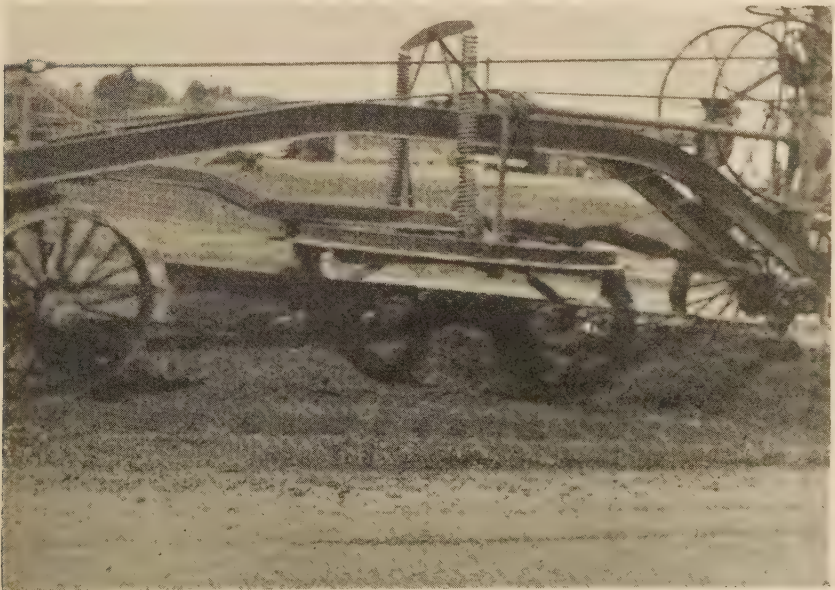
Under a bond issue program of two million dollars for the St. Louis municipal airport, eventually there will be paved in the neighborhood of 350,000 sq. yds. of runways. It was thought not to be best to start with an extensive program until it was found out first what and why we wanted to do such things in this respect. We started with an appropriation from the Airport Commission of \$12,000 to build an experimental runway. After this was completed, 17,000 yds. of 3-in. "black base" and 1-in. sheet asphalt, and then 2000 yds. of 3-in. "black base," and 1-in. binder, with a hot seal coat on top of it. What was learned in the first experimental runway was put into the specifications and two sections of 5000 sq. yds. were started.

It is better first to consider the materials that enter into the construction of the low cost asphalt road, for these airport runways are nothing more than roads which are to be subjected to a new kind of traffic. For the past fifteen years there has been a slow but steady growth of bituminous processing for low cost road programs by the U. S. Bureau of Public Roads in conjunction with various states, and we know that most soils, at one time or another, have been treated with a road oil or cut-back asphalt with varying degrees of success. The information obtained, however, has not been sufficient to cover all the phases, so it was necessary for us to take the materials available and build the best possible pavement. Samples were submitted by five of the large refining companies of their various road oils and cut-back asphalts, which would give satisfactory results with the conditions under which they were to be used.

NATURE OF THE SURFACE SOIL

The surface soil of the St. Louis Municipal Airport, is a black to a very dark brown, heavy silt-loam, 12 to 18 in. deep. The soil is well supplied with organic matter and, when dry, is very mellow and easy to work. It is very "sticky," however when wet, and in a wet condition it is almost impossible to work. The greatest need of this soil was the drainage which was adequately installed over the entire field and, after the paving of each runway, an 8-ft. ditch was dug on each side, parallel to the runway. Tile, varying from 8 to 20 in., were placed for proper drainage and then the trenches were filled with stone, graded between 1 and 2 in.

MUNICIPAL AIRPORT, ST. LOUIS, MO.



CONSTRUCTING MIXED-IN-PLACE ASPHALT RUNWAYS. SHOWING THE THOROUGH MIXING OF AGGREGATES BY MEANS OF BLADE GRADER

The soil, when tested according to the U. S. Master Specification No. 452, gave 1.2 per cent of dried material retained on the 200-mesh sieve. This was sand. The material passing the 200-mesh sieve, but not decanted and known as silt, was 59.7 per cent, while the clay, which was centrifuged out from the decanted solution, was, by difference, 39.1 per cent (Table I). The earth first was mixed with a light road oil. It required about 10 per cent by weight thoroughly to coat all the particles after mixing for 30 minutes, giving only a very light stain. Road oils of higher asphaltic content did not mix so readily but, with proper conditions and manipulation, they could be worked in satisfactorily, whereas the cut-back asphalts were very hard to mix thoroughly on account of the resultant "bally" mixture. It then was noted that if a small percentage of road oil thoroughly was incorporated into the earth, the cut-back would mix very readily. Also if the road oil and cut-back were mixed and then added to the earth the same results would be obtained.

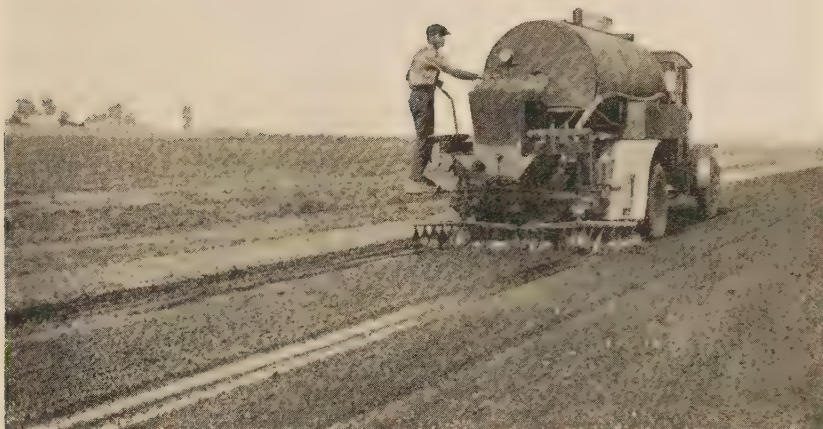
EXPERIMENTS WITH MIXTURES

About forty different combinations of earth, metal and bituminous products were made, noting the ease of manipulation and the stain on each, and a briquette about 4 in. in diameter and 2 in. thick, was made under a compression load of 200 lb. per sq. in. After four days the briquettes were broken and examined as to flexibility and stability as far as the bituminous bond was concerned. A number of mixtures were made, using proportions of 3 parts earth and 1 part stone, but as considerable more asphalt was required with this combination than with an equal part of earth and metal the item of cost entered into the problem. By increasing the metal to about equal proportions of the soil, the asphaltic materials required were less, and consequently reduced the cost of materials. Besides, with the additional metal, a more stable pavement was obtained. The metal used consisted of coarse chats from the lead mine district, which is used extensively in asphaltic concrete pavements, and Iron Mountain stone, the larger particles of which are a very hard stone. The material passing the No. 4 screen (Table I) is composed of crystalline iron aluminum silicates which have the peculiar quality of binding under moist weather conditions.

TABLE I
Mineral Aggregate and Soil Used on Runway at St. Louis Municipal Airport

Soil	Per Cent	Coarse Chats	Per Cent	Iron Mt. Stone	Per Cent
Per cent sand (on No. 200 mesh sieve)	1.2	Ret'd on 3/8 sieve	0.7	Ret'd on 1" screen	2.3
Per cent silt.	59.7	Ret'd on No. 4 sieve	30.5	Ret'd on 3/4" screen	34.1
Per cent clay (by difference)	39.1	Ret'd on No. 10 sieve	32.2	Ret'd on 3/8" screen	34.1
Total	100.0	Ret'd on No. 40 sieve	27.3	Ret'd on 3/16" screen	11.3
		Ret'd on No. 80 sieve	4.3	Passing 3/16" screen	18.2
		Ret'd on No. 200 sieve	3.4		
		Passing No. 200 sieve	1.6		
		Total	100.0		100.0

MUNICIPAL AIRPORT, ST. LOUIS, MO.



APPLYING THE ASPHALT DURING CONSTRUCTION OF SECTION A OF THE RUNWAY BY
MEANS OF PRESSURE DISTRIBUTOR

MUNICIPAL AIRPORT, ST. LOUIS, MO.



LEVELING SECTION B OF THE RUNWAY PRIOR TO ROLLING

The best results were obtained in the laboratory with a heavy cut-back, specific Engler Viscosity at 122 deg. F. between 100-200, and a light road oil with an Engler Viscosity at 122 deg. F. between 5 and 8, but past experience and working this mixture in the laboratory has shown that with this heavy grade of cut-back it would be very difficult to secure a satisfactory uniform pavement. The asphaltic materials giving the next best results were the road oil having approximately 60 per cent asphaltic content with a specific viscosity (Engler) at 122 deg. F. between 20 and 50 and the cut-back which is used for general surface treatment with about 70 per cent asphaltic content and a specific viscosity between 40 and 100 (Engler 122 deg. F.). Working conditions later on in the field substantiated this choice of materials. Besides the choice of materials the following facts were brought out (1) Prime the earth with the road oil and mix thoroughly; (2) Spread the earth and add layer of stone and then add asphaltic mixture to the stone; (3) Use sufficient materials to have equal proportions of metal and earth.

TABLE 2
Analysis of Asphaltic Materials Used in Experimental Runway at St. Louis Municipal Airport

Road Oils

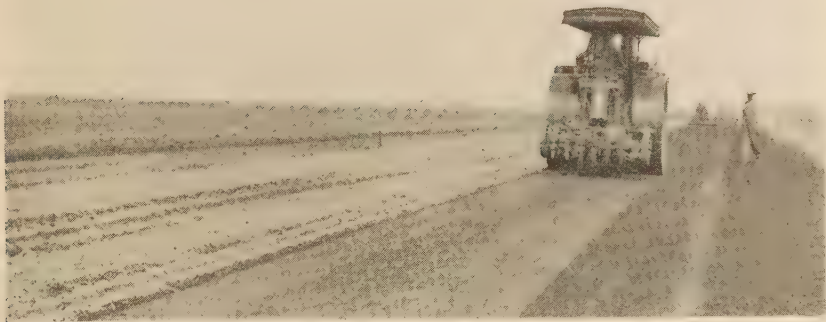
	No. 5 Road Oil	No. 55 Surfac- ing Material	Cut-Backs	
Specific gravity at 60° F..	1.041	0.948	0.956	0.95
Specific viscosity—				
Engler at 140° F.....	21.8	10.9	41.3	18.0
Flash point	350° F.	150° F.	130° F.	100° F.
Residue at 100 penetration	64.5%	58%	70.2%	73%
Ductility on residue 77 F.	110 CM	42 CM	110 CM	110 CM
Solubility in CS ₂	99.7%	99.8%	99.8%	99.6%
Loss on heating	2.3%	15.43%	.....	.....
5 hrs. at 325° F.				

OUTLINE OF CONSTRUCTION WORK

From 1 to 1½ in. of earth and organic material were loosened with a disc and harrow, cut and windrowed with a 12-ft. blade grader and removed by means of Maney graders. The blade grader, throughout the work, was drawn by a 60 hp. caterpillar tractor. In view of the fact that products from two refining companies and some tar products were used, the runway was divided into sections, each 16 by 1200 ft. Each section then was divided into stations 100 ft. in length, and, in this manner, the entire runway was sub-divided and all conditions carefully tabulated.

After the top surface was removed, 2 in. of earth were cut with disc and harrow and then pulverized with a clod breaker and blade grader. The earth then was primed with 0.5 gal. per sq. yd. of road oil, followed by diskings and harrowing, and then was mixed thoroughly with the blade grader. The base next was sealed with 0.3 gal. per sq. yd. of road oil. In order to judge the proper working conditions and verify

MUNICIPAL AIRPORT, ST. LOUIS, MO.



ROLLING SECTION B OF THE RUNWAY, WITH THE STONE ON SECTION A READY FOR THE ASPHALT

the results obtained in the laboratory, three stations of 16 x 100 ft., were worked with the following materials:

(1) Three applications of 0.5 gal. each of the cut-back were made directly to the pulverized earth and were worked in by the use of the disc and harrow, followed by the blade grader. The cut-back asphalt had the tendency to ball and become "gummy" in spots, and was very hard to work to a uniform mix, so much so, in fact, that the volatile matter had evaporated by the time a uniform mixture was obtained and the mixture had set. Road oil later was added before the stone and asphaltic mixture were mixed for the finished pavement.

(2) The asphaltic mixture, composed of 2 parts cut-back (70 per cent asphalt) and 1 part 60 per cent asphaltic road oil, was applied at the rate of 0.5 gal. per sq. yd. The results obtained agreed with the laboratory results and worked out in a satisfactory manner. This combination, principally, was used throughout the runway, with the exception when the proportions were changed to 3 parts cut-back and 1 part road oil as conditions required.

(3) There still existed the opinion, if cut-back asphalt was available, containing about 75 per cent 150 to 200 penetration asphalt having a solvent which would easily penetrate the earth and mix readily and would not dry or cure too quickly, that a pavement would result which would be mealy and plastic rather than tightly bound and adhesive. With this view in mind an asphaltic mixture of the following analysis was used:

Specific gravity at	60° F.	0.969
Specific viscosity (Engler) at.....	122° F.	55.4
Viscosity (Furol) at.....	104° F.	405
Viscosity (Furol) at.....	122° F.	206
Viscosity (Furol) at.....	140° F.	119
Flash point	215° F.	

Distillation by A.S.T.M. Method D — 20 — 28 — T

Percentage off at 518° F.....	4.6
Percentage off at 600° F.....	13.4
Percentage off at 680° F.....	17.9
Viscosity of residue (Furol) at 400° F.....	13
Viscosity of residue (Furol) at 350° F.....	17

The results obtained with this product were so satisfactory that it was included as an alternate specification for the bituminous mixture of cut-back and road oil in the two sections of experimental runways which were let to contract, the operations of which are mentioned later in this article.

SPREADING OF THE STONE

After the priming with road oil, 1 in. of stone was spread over an entire section with a Bangert Bros. stone spreader. This was followed with an application of the asphaltic mixture (cut-back asphalt 2 parts, and road oil 1 part). The asphaltic mixture was always applied at the rate of about 0.3 gal. per sq. yd. by making several trips across the work until the treatment had been applied. This usually was between 1 and 1.5 gal. A thorough mixture was obtained either by the blade grader of a maintainer, before the second and third additions of stone and asphalt. Certain areas needed more asphalt than others and this always was applied before the final mixing. Then the pavement was rolled with a 10-ton, 3-wheel roller. The proportion of materials used in each section are as follows:

TABLE 3

Quantity of Material Used in Each Section of Runway, St. Louis Municipal Airport

Section	Road Oil, Gallons	Cut-Back, Gallons	Total Gallons	Gallons per sq. yd.	Stone and Chats, Pounds per sq. yd.
A	3,303	3,705	7,008	3.18	184
B	4,779	4,001	8,780	3.44	184
C	2,050	4,800	6,850	3.10	176
D	2,831	3,867	6,698	3.04	170
E	2,850	4,500	7,350	3.43	189
F	1,000	*7,218 Tar	8,218	3.72	201

Area of each section 2,200 sq. yds.

*Tarvia B Special; specific viscosity Engler at 40° C. 25-40

One section of runway was made with tar as follows: The base was sealed with Tarvia A, followed by the application of the stone which was rolled into earth. After another ½ in. of stone and an application of Tarvia B Special, which gave better results than other brands of tar

for this purpose, had been applied, enough earth to fill the voids was brought in with the blade and rolled. Then followed the third application of stone and tar and earth. The pavement was built, one layer upon another, without mixing to a homogeneous mass. After the final application of tar the maintainer was used thoroughly to mix the top layer of material and then came the final rolling.

In building this experimental runway there were some defects and, in some instances, working conditions were not of the best. For instance, at one time, heavy rains came before the final rolling and this, no doubt, eventually will show up some time this winter and next spring. After these rains about 300 ft. of the runway were under 3 in. of water and some the earth had not been mixed with any asphaltic material. Consequently there was more moisture in this earth than was desired. The subgrade, under these 300 ft. of pavement, is also very weak and no doubt will cause some damage, but as yet it is in a satisfactory condition.

For a seal coat, about 0.15 gal. per sq. yd. of the asphaltic mixture was applied over the entire runway. Then, in order to have a uniform grade, some stone was spread and mixed with cut-back asphalt and the depressions filled. About 15 lbs. per sq. yd. of coarse chats were spread and rolled and the final seal of a light cut-back was applied at the rate of 0.15 gal. per sq. yd. The pavement, as it now stands, consists of a well drained subgrade, a sealed base preventing moisture from entering the pavement by capillary attraction, and a resilient asphalt, earth and stone mixture 3 inches in thickness, with a waterproofed non-skid surface. Having learned a number of very important features in the construction of this runway we let contracts for two more so-called experimental runways of 5000 sq. yds. each, embodying the following features:

EQUIPMENT

Two tractors, at least one of which shall be of 10-ton capacity.

One gang plow.

One double-disc harrow.

One blade machine of at least 12-ft. blade.

One road maintainer.

One self-propelled 8-ton tandem roller.

Asphalt distributors of a satisfactory character.

METHODS SPECIFIED FOR TYPE "B" RUNWAY

- (1) All sod and organic material shall be removed from the area to be paved as the runway.
- (2) Area to be treated shall be plowed to a depth of 4 in. and thoroughly pulverized with disc and maintainer.
- (3) Application of 0.5 gal. of road oil to the sq. yd. to every 2-in. thickness of earth and incorporated thoroughly.
- (4) After treatment of oil, material shall be removed from area being worked by means of blade machine and shall be placed in windrow.
- (5) Area being worked then shall be graded uniformly to a subgrade 4 in. below the finished surface and rolled.
- (6) Application of 0.33 gal. of road oil to seal the base. On top

MUNICIPAL AIRPORT, ST. LOUIS, MO.



ROLLING SECTION B OF THE RUNWAY, AUGUST 16, 1929. ROLLER SURFACES KEPT WET WITH WATER

of oiled subgrade, $\frac{3}{4}$ in. of oiled earth shall be spread from the windrow. On this layer approximately 0.6 gal. of bituminous mixture. A second layer of oiled earth, followed by 0.6 gal. of asphaltic material.

- (7) Thorough mixing with blade machine or maintainer, and, if necessary, an addition of asphaltic material and mixing.
- (8) Rolling with 8-ton tandem roller.
- (9) Two more layers of oiled earth, each followed by approximately 0.6 gal. of bituminous products.
- (10) Upper layers then thoroughly mixed, leveled and rolled; at this time pavement to be 3 in. thick.
- (11) Upon finished 3 in. of pavement, a treatment of 0.25 gal. of cut-back, followed by a layer of stone, to such amount that at least $\frac{3}{4}$ in. be added to the pavement. Application of 0.25 gal. cut-back, followed by thorough mixing with maintainer. It shall then be leveled off, rolled and covered with stone chips (20 lb. per sq. yd.). Final application of cut-back asphalt at the rate of 0.1 gal. per sq. yd. and 10 lb. per sq. yd. of stone chips, whereupon the whole shall be rolled thoroughly until compact and true to grade.

CONSTRUCTION OF TYPE "C" RUNWAY

This specification is intended to produce a runway pavement 4 in. in thickness after completion, consisting principally of stone, the voids of which shall be filled thoroughly with asphalt-treated earth.

Operations:

- (1) Organic material removed and 2½ in. of earth cut, pulverized and mixed thoroughly with 0.5 gal. of road oil.
- (2) Subgrade rolled and sealed with 0.33 gal. of road oil. Layer of 1 in. of loose coarse stone, followed by 0.75 gal. of cut-back asphalt. Sufficient oiled earth from windrow to fill voids in stone.
- (3) Materials leveled off and second layer of stone (1 in. thick) followed by 0.75 gal. of cut-back asphalt. Again there shall be bladed over the surface sufficient oiled earth to fill the voids in this second course.
- (4) The whole of the material on the subgrade then shall be worked thoroughly, with blade machine and maintainer, until the excess cut-back asphalt shall be combined thoroughly with the impregnated oiled earth and the whole shall be mixed completely with the asphalt-coated stone. Additional asphalt may be added if necessary.
- (5) Treated material, as above described, shall then be leveled off to a true surface, paralleled to the intended finished grade.
- (6, 7, 8, 9) Upon the surface of finished lower layer, as above described, an additional layer of stone shall be spread and a second complete layer of the same character shall be built up in the same manner as described in operations 2, 3, 4 and 5.
- (10) Upon the compacted and finished grade there shall be an application of 0.15 gal. of cut-back asphalt covered with a layer of stone chips (20 lbs. per sq. yd.) and thoroughly rolled to a true grade.

We will now have the pictures, but, first, I want to say that we have no pictures showing the removal of the organic matter. That idea did not occur to us until we had a couple of sections built, but we have enough to follow all the application and mixing of the bituminous products with the earth and stone. This work was conducted under the supervision of Mr. W. W. Horner, who is the consulting engineer for the Airport Commission and is the chief engineer of sewers and pavements.

PROVISION FOR FUTURE WIDENING

I think, on a runway where we have under construction 100,000 yards or more, it might not be a bad idea to put rubber tires on the grader, for it has a tendency to pick up a great deal of material and to cut through the seal that is put on the subgrade. You will note that the stone was always placed and then the bituminous material added to the stone and thoroughly mixed. After each application the whole was mixed thoroughly, so there were no uncoated particles whatsoever. This picture shows the last application and the mixing. The blade of the grader was raised gradually, leaving a small amount of material. As you come up, you have a close view of the coarse chips and one of the fine.

These runways all were built on a plane eventually to be widened to 200 ft. with no crowns. The next picture was taken after another application. Note the thorough mixture. On the entire building of one section we averaged around twenty-five round-trips of the grader, or maintainer—twenty-five trips of the equipment across the section. The maintainer works very good, where you are mixing 2 in. but, where you

are mixing more than 2 in., the blade grader should be used. Note the track where the wheel of the grader went.

The next view is of the untreated section. The next was taken before the final seal coat was put on and after the stone had been added. The runway was allowed to cure for a couple of weeks before the final seal coat was put on. This picture shows the dust the aviator raised whose plane was right alongside of the runway where he took off. The runway is in the center of the picture. We have another reel showing the 3-in. "black base" and the 1-in. top, and the work of laying them.

MUNICIPAL AIRPORT, ST. LOUIS, MO.



SECTION B OF THE RUNWAY PRIOR TO SPREADING THE LAST LAYER OF MATERIAL.
NOTE LINE IN LEFT FOREGROUND DUE TO GRADER WHEELS

There was some discussion in the papers yesterday on the subgrade and the moisture of the soil, and it might be well to tell you something about the subgrade sections we have out there. On this runway where we had that 3 in. of water after a rain and where the trenches were dug afterward along the sides of the runways, we went down about 6 ft. in this low spot and found a stream of water. We put in 12-in. piles, I think it was about halfway, and just as fast as we put the piles in, it was being drained. At the present time however, the water is there and I do not think the drains will take the moisture out of this subgrade this winter. The "black base" consisted of graded stone with about 5 per cent asphalt put on, in accordance with the yardage basis. In any low spots that showed up, we used asphaltic concrete stone with the bituminous mixture $\frac{1}{2}$ in. down. This was put in and leveled up before the top was put on. The next picture shows a subgrade which was thoroughly rolled before putting this on.

This picture shows the dumping and spreading of the "black base." This was put on across the runway, in about 20-ft. strips each of the length of a 100 ft., and working crossways all the way down. That is the material used to bring the "black base" up to grade. Quite a number of aviators insisted that the concrete pavement on the top was a very rich top. The asphalt cement set very readily. It was about a 6 per cent asphalt. There is a great difference of opinion as to whether that is a proper surface or not. I think the sheet asphalt may be too smooth and that is the reason we put in the 2200 yds., with 1-in. binder and the hot seal on top of it, to give us a little bit of everything. We will know more about it next spring.

APPLYING THE HOT SEAL COAT

This picture shows the work of applying the hot seal coat. We were in a big hurry that morning. The "Good Will Tour" came in about twenty minutes after we finished work. The field manager was driving everybody crazy and urging them to get off the field. The first plane to land, I think, perhaps was Captain Hobson with the Texaco plane, and the photographers caught a picture of him in the act of landing. The surface shown in this picture was not put on in any experimental sense, except possibly for the frost action this winter. However, they wanted one runway in the direction of the wind, and this was constructed so that aviators could have some place to come into and get away from during the winter.

I might add that on the subgrade we had a couple of places where the trucks drove on to it when they were hauling stones for the "black base." They were not supposed to drive on there and they broke down a couple of places. The subgrade was absolutely dry when the "black base" was put on and, afterwards, when the drainage was put on, these places broke down. We tore out a couple of places and replaced them. We found plenty of water immediately under these broken places. The sidewalk was absolutely wet. That is one reason why I think it is too late in the year now for the installation of proper drainage. We will get plenty of experience from the frost action however during the winter.

CHAIRMAN KENNEDY: The next paper will only take a few minutes, and as your Committee on Resolutions has requested a few moments at this time to report the resolutions it has prepared, I will take the liberty of delaying the reading of the next paper until the resolutions have been presented. The report of the Committee on Resolutions will be read by Mr. Frank B. Curran of Washington, D. C., a member of the committee. Mr. Curran, at this juncture, will you please take charge of the meeting? Gentlemen, Mr. Curran!

Report of the Committee on Resolutions

Presented by Mr. Frank B. Curran, Washington, D. C.

Highway Specialist, Automotive Division, United States Department of Commerce

Gentlemen of the Eighth Annual Asphalt Paving Conference:

Your Resolutions Committee, consisting of the following delegates: A. K. Vickery, Denver, Colo.; H. S. Fairbank and F. B. Curran, Washington, D. C.; A. H. Hinkle, Indianapolis, Ind.; F. A. Hogan, Toronto, Ontario, Can; C. C. Lakin, Chicago, Ill.; C. S. Lee, New York, N. Y.; R. H. Simpson, Columbus, Ohio; H. J. Hughes, Cambridge, Mass.; B. E. Gray, Keyser, W. Va.; J. T. Bullen, Shreveport, La.; Chas. S. Pope, Sacramento, Cal.; Bryson Valles, New Orleans, La.; E. R. Dutton, Minneapolis, Minn., and B. P. McWhorter, Atlanta, Ga., begs leave to submit, for adoption by this conference, the following resolutions:

FEDERAL AID FOR ROADS

WHEREAS, It is the firm belief of this conference that no Federal appropriations have yielded returns more beneficial to the country generally than those that have been made for Federal Aid road construction; and

WHEREAS, These beneficial returns will be increased as the designated system of Federal Aid roads is further improved to a degree consistent with the demands of the important traffic which it serves; and

WHEREAS, It is desirable that such further improvement shall be prosecuted as rapidly as the work can be executed with economy and efficiency in order that the further anticipated benefits may be realized without unnecessary delay; therefore, be it

RESOLVED, That this conference strongly urges upon the Congress of the United States the desirability of authorizing appropriations for the purpose of Federal Aid in the amount of not less than one hundred and twenty-five million dollars (\$125,000,000) annually, beginning with the fiscal year 1931.

RESOLUTION OF THANKS

WHEREAS, The West Baden Springs Hotel Company has been most diligent, courteous and obliging in caring for this conference, making our stay here a most enjoyable one in accordance with each courtesy extended, and

WHEREAS, Numerous public officials and others, as presiding officers, speakers and entertainers, have contributed toward making this conference one of the most instructive and successful ever held; therefore, be it

RESOLVED, That the thanks of this conference be and hereby are extended to the West Baden Springs Hotel Company and to all those who have contributed so splendidly to the program and the entertainment of the conference.

PAN-AMERICAN HIGHWAY

WHEREAS, Highway development is of immediate importance to the social, economic and political progress of the countries that are members of the Pan-American Union; now, therefore, be it

RESOLVED, That the delegates to the Eighth Annual Asphalt Paving Conference assembled in West Baden, Ind., cordially indorse the work being done by the Pan-American Union in this direction and urge that the members of the Congress of the United States give whatever support may be necessary to this work, to the end that the two American continents may be more closely joined together by a more adequate highway system in friendly relationship and understanding.

HIGHWAY ADVERTISING SIGNS

WHEREAS, Advertising signs along the public highways not only destroy the scenic beauty, but create a serious traffic hazard by distracting the attention of drivers; therefore, be it

RESOLVED, That we reaffirm the position previously taken by this conference at Atlanta, Ga., in 1927, and at New Orleans, La., in 1928, against the encroachment of advertising signs on our highways and, in the interest of safety and the promotion of scenic beauty, we urge the several states which have not already done so to bar all advertising signs from the highways by legislation prohibiting such advertising within 500 ft. of the right of way.

CANADIAN COOPERATION

WHEREAS, The highway officials of the Dominion and provincial governments of Canada, as well as the engineers, technologists and contractors in that country, have been manifesting increasing interest in this conference from year to year, and

WHEREAS, There is present at this meeting a large delegation from Canada which has honored us with its presence and has participated in our sessions; therefore, be it

RESOLVED, That the Eighth Annual Asphalt Paving Conference, meeting at West Baden, Ind., extends to these most welcome guests from our friendly neighbor on the north our sincere thanks for the interest they have taken in this meeting, our appreciation of their coming and our gratitude for the contributions they have made to the success of this conference; and, be it also

RESOLVED, That we express the hope that they have enjoyed their visit with us and that they will continue their interest in our meetings during the years to come so that we may welcome them hereafter in ever increasing numbers and may reciprocate their good will and kindly considerations. We wish for them a safe journey homeward and we shall ever remember their visit with pleasure and profit.

GOOD ROADS ABROAD

WHEREAS, The Highway Section, Automotive Division, of the Bureau of Foreign and Domestic Commerce, United States Department of Commerce, is engaged in a world wide campaign to bring to the attention of the various nations the advantages of good roads and the construction thereof with American technical assistance, machinery, methods and materials and, at the same time, is engaged in collecting information through the foreign offices of the Department of Commerce and the Department of State relative to all the phases of highway construction and development abroad, and is publishing this information for the benefit of American firms, thus assisting to develop and increase foreign markets for products such as asphalt, and

WHEREAS, We believe that the work being done by the Highway Section is most important to the American road building industry, that it is promoting the extension in particular of the market for American road building materials and machinery abroad, improving the economic condition of various countries and stimulating freer intercourse between nations, as well as promoting a higher standard of living and establishing greater good will, peace and harmony between the nations; therefore, be it

RESOLVED, That the Eighth Annual Asphalt Paving Conference, meeting in West Baden, Ind., heartily approves the work being done by the Highway Section, Automotive Division, of the Department of Commerce and urges the highway industries and technologists and those in administrative control of paving to lend their hearty support to said educational campaign abroad and to avail themselves as fully as possible of the facilities afforded by the Department of Commerce for supplying information relative to markets for the sale of materials and equipment and the construction of paved roads throughout the world, and

WHEREAS, The work being done by the Bureau of Mines and Minerals Division, Bureau of Foreign and Domestic Commerce, in collecting, segregating and disseminating information relative to the production, consumption, export and import of asphalt is of great value to the asphalt industry, and, be it further

RESOLVED, That the Department of Commerce be requested to provide if possible even more complete and detailed statistics of this nature, in order that the asphalt industry may be more promptly and fully advised concerning its status from time to time, both at home and abroad.

FARM-TO-MARKET ROAD IMPROVEMENT

WHEREAS, There are in the United States approximately two and a half million miles of roads still unimproved, and

WHEREAS, The lack of good roads connecting the vast majority of American farms directly with their markets or with the improved state and Federal Aid roads which lead to the markets, is the cause of great losses to agriculture annually, and

WHEREAS, No greater assistance can be given to agriculture than by improving transportation facilities from the farms to the markets, and

WHEREAS, The orderly and regular delivery of the mails in rural districts is greatly hampered, delayed and made more costly by inadequate rural roads, and

WHEREAS, Congestion on the improved highways of the United States, with its consequent increase in the number of motor accidents which cause great loss of life and property and decreased efficiency in highway transportation, has a detrimental effect upon the social and economic welfare of all classes of citizens; therefore, be it

RESOLVED, That it is the sense of the Eighth Annual Asphalt Paving Conference in session at West Baden, Ind., that every legitimate effort should be made by the duly constituted authorities to study and plan a systematic improvement of the greatest possible mileage of farm-to-market roads at the lowest cost, consistent with the results to be obtained, having in mind not only the expense of the first improvement but the annual maintenance costs necessary to keep these roads in service throughout all the months of the year, and that the Congress of the United States and the legislatures of the various states be requested to authorize and facilitate the study, by the various authorities charged with the administration of our highways, of definite and detailed plans for financing and executing the reconstruction, improvement and maintenance of the great mileage of unimproved roads upon which the farms and rural districts of the United States must now depend, and, be it further

RESOLVED, That copies of this resolution be forwarded to the President of the United States, the Congress of the United States and to the governors and legislatures of all the states.

NATIONAL TRANSPORTATION SURVEY

WHEREAS, The social and economic welfare of the people of the United States, in great measure, is dependent upon adequate and efficient means of transportation, and

WHEREAS, The extraordinary growth of highway transportation in recent years, the rapid development of aviation and the reawakening of interest in the inland waterways are bringing about revolutionary changes in the distribution of manufactured goods and agricultural, forest and mineral products, and

WHEREAS, These changing conditions of distribution have vitally affected the economic and social welfare of our whole population, and

WHEREAS, Under the present conditions the necessary coordination of the various forms of transportation has not yet been fully attained, the development of our inland waterways has not been completed and there is a lack of information as to the cost of highway transportation as well as comparative costs of this with other forms of transportation, and

WHEREAS, It seems essential to the economic progress of our country that these questions should be solved; therefore, be it

RESOLVED, That it is the sense of the Eighth Annual Paving Conference, in session at West Baden, Ind., that a suggestion be laid before the President of the United States to the effect that a transportation survey of the United States be made by a commission composed of members appointed by the President from the Department of Agriculture, the Department of Commerce, the Interstate Commerce Commission, the National Research Council and the leading organizations interested in the development of the various forms of transportation; this survey to include a study of the extent to which each form of transportation is being utilized, the cost of transportation of freight and passengers by each medium, the amount of duplication or overlapping of services, with recommendations for a more complete utilization of the roads, inland waterways, air services, etc., it being understood that the activities of the commission would be in cooperation and harmony with any specific studies now being made by the Interstate Commerce Commission or similar agencies.

HIGHWAY RESEARCH ACTIVITIES

WHEREAS, Very great economies in road construction could be realized if data were available on certain economic and technical problems now affecting road work, and

WHEREAS, A large number of different agencies are carrying on research work on these problems independently and with little co-ordination of effort, and

WHEREAS, It seems essential that these scattered activities should be coordinated, the results correlated and provision made for the fullest dissemination of such data; therefore, be it

RESOLVED, That it is the sense of the Eighth Annual Asphalt Paving Conference, in session at West Baden, Ind., that we offer the fullest support possible to the agencies now engaged in research work on highway problems, and express our approval of the effort being made to coordinate these activities; and, be it further

RESOLVED, That the Eighth Annual Asphalt Paving Conference commends the efforts of the National Research Council to solve these important highway problems and the work it is doing in cooperation with the other agencies of a similar character.

Respectfully submitted,

A. K. VICKERY,
Chairman.

C. S. LEE, Secretary.

MR. F. B. CURRAN: Mr. Chairman, I move that these resolutions be adopted.

The motion was seconded by Mr. C. S. Lee and was carried unanimously.

CHAIRMAN KENNEDY: The next paper we have this morning is by Mr. John A. Herlihy, chief engineer of the Transcontinental Air Transport, Inc., and is entitled "Oiled Runways for Airports." Gentlemen, Mr. Herlihy!

Oiled Runways for Airports

By J. A. Herlihy, St. Louis, Mo.

Chief Engineer, Transcontinental Air Transport, Inc.

The rapid increase in air traffic in the past few years has brought forcibly to mind the necessity of paved runways for airports. The purpose of this paper is to point out the necessity for such runways and to describe the methods of building them, with particular reference to the use of asphalt paving. The two main reasons for the necessity of paved areas are, first, to insure the operation of heavy transport planes during wet weather and, second, to eliminate the dust nuisance so long associated with airports. This latter item, together with the smooth landings and take-offs possible on paved runways, is very important to passenger carrying air lines.

SIZE OF RUNWAYS AND LANDING STRIPS

It obviously is impracticable to consider paving or surfacing the entire area of an airport. The natural solution is to surface certain areas of the field called taxiways and runways. The size of the runways has been a subject of much discussion. For runways which are to be used as take-off strips only, 90 ft. is an ample width. For landing strips the runways should be at least 120 ft. in width. It is true that under ideal conditions a pilot can land his plane on a very narrow runway, but if there is a cross-wind, if one tire is flat, or if one brake should stick a little, a 120-ft. width is about as narrow as it is safe to use. Then there is also the problem of turning the ships around on the runways. Again, under ideal conditions, a pilot can brake one wheel and turn very sharply, but in a strong wind it is difficult to handle planes on the ground.

The length of runway required varies with the altitude above sea level. Runways, in general, do not need to be the full length of the field, but, at sea level, where the Department of Commerce requires 2500 ft. of clear field, the paved area should be at least 1500 ft. of that length. At 5000 ft. above sea level, the Department of Commerce requires runways about 4000 ft. long, but 2500 ft. of paved area ordinarily is sufficient.

There have been as many different methods of airport surfacing as there have been of highway surfacing. These include gravel, sand-clay, cinders, oil and asphalt pavements of all types and concrete. In this paper only the oil or asphalt paving will be discussed.

STRENGTH OF ASPHALT RUNWAYS

Properly designed asphalt paved runways easily will support the weight of the heaviest transport planes and give a smooth, resilient, dustless surface. They are not prohibitive in first cost and are easy to install and maintain. The chief objection to oiled runways is their color. For night landings, the problem of properly lighting an airport having oiled runways is more difficult than if the runways were of a light color. If an asphaltic compound of a light sand or cream color can be developed it will be a real step forward in airport runway paving. If white strips

about 4 ft. in width are built at the borders of the runway, it will help materially in off-setting the light absorption by the black pavement.

There are many different types of oiled runways, each suited to a special purpose. Hard, smooth pavements are desirable for taxiways and areas near passenger stations, etc. Hard runways are also very desirable as take-off strips, but, for landings, a softer, more resilient surface is desirable. The Grand Central Air Terminal at Glendale, Cal., is an example of a field with separate take-off and landing strips. The take-off strip is of concrete 3000 ft. long and 72 ft. wide, flanked on both sides by a strip of asphalt 12 ft. in width. The landing area is approximately 400 ft. wide and 3500 ft. long. It consists of a 4-in., mixed-in-place, "plastic-mix," oil pavement. This arrangement is very satisfactory. If a runway is to be used for both landings and take-offs, it should be fairly soft and resilient.

RESILIENCY DESIRED IN RUNWAYS

Extremely hard runways are very hard on airplane tires, which, of course, have to be built as light as is consistent with safety anyway. Consider a plane coming in at 55 to 60 miles an hour and the force which is necessary to start a wheel, 40 in. in diameter, weighing 92 lbs. instantly spinning at the rate of 500 r.p.m. Obviously, the wheel cannot start spinning at that speed instantaneously and there must be a give, either in the tire or in the pavement. If the pavement is too hard it will burn the tire severely at the instant of contact and will shorten greatly the life of the tire. If you stand near a plane landing on a hard runway you will hear a sharp shriek as the tire comes in contact with the runway. Softer landing strips of the "plastic-mix" type, are, for this reason, far preferable for landing areas. Another point to be considered is that small ships, equipped with tail-skids, which ordinarily prevent ground looping, are apt to get into serious difficulty on a hard pavement.

The methods of producing the harder pavements are the same as those used in highway work and will not be discussed in this paper. The softer, "plastic-mix," landing strips offer a slightly different problem however, and a description of the methods by which these were built on several fields in the southwest will be described. The method, in general, was as follows:

ANALYZING THE NATURAL SOIL

The runways were made by the "mixed-in-place" method. In other words, the oil and the soil were mixed-in-place on the ground. The method is adaptable readily to desert country having a fine, sandy soil containing not too much organic material or containing not more than a trace of calcium sulphate or sodium sulphate. The process, however, has been used on a wide variety of soils.

The first step is to analyze the natural soil, which should show a fairly uniform grading from 200 mesh up to $\frac{1}{2}$ in. If the natural soil is not properly graded, it will be necessary to bring in foreign material of such a size as to make a uniform grading of the mix between the limits given above. The thickness of the runway will depend entirely upon local conditions. If its function is almost entirely that of dust protection

and there is no problem from rain, with the possibility of bogging down the plane, then about a 2-in. cake will be sufficient. If it is necessary to build a runway which will hold up under heavy rains, it should be about 4 in. in thickness.

The runway is prepared for the application of the oil by a thorough harrowing with a disk harrow and thoroughly mixing the natural soil with the foreign material, if foreign material is used. After mixing the soils, the oil is applied through a force-feed spreader in separate applications, of approximately one-half gallon per square yard. The oil used in one instance was a 60-70 per cent asphaltic oil of 80 penetration, at 77 deg. F. After each application the runway again is harrowed thoroughly to mix the oil and soil. Ordinarily, it will take about three-fourths of a gallon of oil per square yard per inch of thickness of runway. The finer the material the more oil will be necessary.

After all of the oil has been applied, it is mixed by blading it back and forth across the runway with an ordinary blade grader set at an angle of about 45 deg. with the direction of travel. This blading serves thoroughly to mix the oil and the soil and is a very important part of the process. It will be necessary, ordinarily, to blade the mix from twenty to thirty times so as to get a thorough combination of the materials. In wide runways, it will be advisable to blade up the material into windrows about 15 ft. apart and then blade it back and forth. When the material is mixed thoroughly, it will have a dark chocolate appearance in the windrow and will be thoroughly uniform in color. The mixture should be "live" and should tend to "crawl" when disturbed with a stick or other instrument.

LAYING THE SURFACE MATERIAL

The next process is to lay down the material on the surface in a layer of uniform thickness. This is done with a straight blade and requires very careful work to get a good job. After it is laid down the material should be rolled with a light roller, or, preferably, by a truck with large pneumatic tires. This will seal the surface as well as compact the material underneath. It will probably not be advisable to use a heavy roller which would be liable to leave waves in the surface.

Care should be taken not to apply any oil or attempt to do any mixing while the materials are wet. These runways will give a smooth, tough and resilient surface, excellent for the landing and taking-off of airplanes. If material not over $\frac{1}{2}$ in. in size is used, they will remain fairly soft, permitting ships with tail-skids to land comfortably with little danger of ground-looping. If harder runways are desired they could be obtained by using coarser material, say up to 1 in. in size. We made runways in this way on one of our fields and they have set up very hard, similar to macadam roads.

The chief advantage of these methods over others is the saving in cost and the ease of construction. They can be built for less than half as much as almost any other form of paving and, for most conditions and rather dry countries, will give equally as good results. By carefully handling the drainage problem and using under-drains, they readily could be adapted to country having considerable rainfall. To give you some

specific examples of the way in which some particular problems have been handled, I will describe the work at two of our fields.

At Winslow, Ariz., the soil was composed of a fine red sand and silt. The mechanical analysis and classification were as follows:

Mechanical Analysis

Sieves	Per Cent Individual	Per Cent Cumulative
Passing 200 mesh	14.8	14.8
Passing 100 mesh	22.6	37.4
Passing 80 mesh	6.2	43.6
Passing 50 mesh	9.8	53.4
Passing 40 mesh	4.2	57.6
Passing 30 mesh	6.5	64.1
Passing 20 mesh	5.6	69.7
Passing 10 mesh	2.6	72.3
Passing $\frac{1}{4}$ mesh	8.8	81.1
Passing $\frac{1}{2}$ mesh	10.4	91.5
Passing $\frac{3}{4}$ mesh	5.3	96.8
Passing 1 mesh	3.2	100.0

Classification

Clay	3.8%
Silt	11.0%
Sand	57.5%
Rock	27.7%

This soil, in its natural state, would take oil readily and would very likely have made a good pavement. However, on account of the large percentage of fines, it would have taken an excessive amount of oil and would have been very difficult to work. The areas which we had dragged over and smoothed up were covered with a fine, floury soil, ankle deep in places, so it was decided to use sand and gravel in connection with the natural soil.

APPLICATION OF THE ROAD OIL

About two and one-half inches of sand and gravel, all passing a $1\frac{1}{2}$ inch screen on a 45° slope, were used. This was spread over the runway area evenly and then was gone over with a heavy disk harrow so as to mix it thoroughly with the natural soil. The oil then was applied with a force-feed spreader at the rate of 1.9 gallons per square yard, applied approximately one-half gallon at a time. Between applications the runway was gone over thoroughly with a disk harrow to start the mixing and to bring fresh material to the surface. (It might be mentioned that the surface was so soft at times that we had to use a tractor to haul the oil truck.)

After the final application of oil the runways again were disked in two directions, and then mixing with the blade was started. The blade was set at 45° , and just low enough to catch all the material which had received oil. The mix then was bladed back and forth in windrows about

fifteen feet apart until it was a uniform chocolate brown in color. This required 22 turnings. Then the windrows were laid down to form a smooth material three inches in thickness over the entire area. Dragging with a heavy road planer was attempted in order to compact the mix, but it had a tendency to bring the larger gravel to the surface. This was not desirable, so use of the planer was discontinued.

Traffic compaction, of course, is ideal for this type of paving, giving a compaction from the ground up. Therefore, trucks with large pneumatic tires were run up and down the runways, followed by a light roller, run transversely so as to smooth out all the tire marks. The result was a smooth, resilient, waterproof surface, which has held up well under very severe rain storms this summer. The runway finally set up quite hard, due to the coarse gravel which was used. Had the size of gravel been kept down, and under $\frac{1}{2}$ in. in size, a softer pavement would have resulted.

APPLYING SAND AND OIL AT WAYNOKA

At Waynoka, Oklahoma, the situation was somewhat different. The natural soil was a fine, red, clay material which baked almost as hard as a brick but slumped down immediately upon being wet. The mechanical analysis and classification were as follows:

Mechanical Analysis

Sieves	Per Cent Individual	Per Cent Cumulative
Passing 200 mesh	83.2	83.2
Passing 100 mesh	13.5	96.7
Passing 80 mesh	1.5	98.2
Passing 50 mesh	1.5	99.7
Passing 40 mesh	0.3	100.0

Classification

Clay	57.4%
Silt	25.8%
Sand	16.8%

The chemical analysis showed that the natural soil would take oil and that procedure was recommended. However, from a practical viewpoint it was feared that great difficulty would be found in mixing such a soil with the oil, so two inches of pit-run coarse sand, all passing a $\frac{3}{4}$ -inch screen, was used in connection with the natural soil.

The sand and oil were applied as before, but, while the ground was dry, it was so hard that it was very difficult to get any natural soil into the mix to supply the fines. When it was wet it was almost impossible to get on to the field at all and, of course, the wet soil and the oil would not mix. Finally, sufficient natural soil was brought up, but it was in lumps varying in size from a small pea to a good sized marble. Numerous methods were tried to break these particles down but all were unsuccessful. By this time the mix had been worked so much that most of the volatile oils had escaped, leaving it very dry.

It was decided to apply $\frac{1}{2}$ gallon of lighter oil (50-60% asphalt) to serve a double purpose. First, to bring the whole mix back to a workable mass and, second, to supply an excess of oil in the runway so that, as the small particles of soil broke down under traffic and wet weather, there would be sufficient oil present to saturate them and cause them to become incorporated in the general mix. This procedure has been successful and the runways have stood up well under heavy rainfall. Due to using smaller gravel, these runways are softer and more resilient than those at Winslow.

IMPORTANCE OF PROPER DRAINAGE

The methods described will work very well in the dry southwestern country. For northern and eastern fields it will be necessary to put in a much more substantial base, with the plastic mix material in a layer two or three inches thick on top. The proper drainage for such fields and runways is, of course, of primary importance. However, the scope of this paper does not permit discussion of this subject.

The present trend in air transportation is toward larger and heavier planes, which will make the paving of runways on airports even more necessary than at present. As it has been pointed out in this paper, these runways should be of two classes, the hard surfaced taxiways and take-off strips, and the softer and more resilient landing areas. Asphaltic oils readily lend themselves to the building of both of these types of airport paving and, undoubtedly, the members of the Asphalt Association will play a very important part in building the airports of the future.

CHAIRMAN KENNEDY: Mr. W. E. Rosengarten of the Asphalt Association, New York, has a few slides and a short discussion that will take about five or ten minutes and we will ask him to present them at this time.

Utilization of Local Materials for Paving at Airports

By W. E. Rosengarten, New York, N. Y.

Traffic Engineer, The Asphalt Association

The papers that we have had in previous sessions of this conference have disclosed a wide variety of asphaltic types for highway purposes. Now that we have a new field, that of paving at airports, with its new problems of surfacing rather extended areas and the cutting effect of tail-skids, it certainly should arouse the interest of the highway engineer to design a pavement that economically will fill these new requirements. Already new types are being introduced. For instance, we have heard, in the Southwest and the West, of the mixed-in-place construction, where the local materials are mixed on the road or runway with liquid asphalt. But in the East, which was the first section of the country to build highways, that type of construction for airports has been unknown until the past summer. It was introduced as a paving at one of the airports on Long Island.

So I think that airport construction is opening a new field which should be of interest to all highway builders. On account of the variety of asphaltic types and the suitability of asphalt for construction with local materials, we have possibilities for low cost construction involving dustlessness and other advantageous factors. It, therefore, is natural to find that the asphaltic types are now being used quite extensively for this construction work. It is interesting to note too, that, according to a summary recently made, asphaltic types of construction have been used at some fifty-three different airports in this country for runway construction, taxiways, aprons and hangar floors.

GETTING AIRPLANES OUT OF THE MUD AND DUST

I have a few slides which illustrate the asphalt construction at several of the airports in different parts of the country that may be of interest at this time. The need for a paved runway first, is safety. Accidents have happened, due to soft fields, which have caused very serious loss. Another need for runway construction of the bituminous type is that of laying the dust, which is quite objectionable about an airport. Here we have a view of the airport at Newark, N. J. The runways have been built of an asphaltic type, but there are warming-up spaces that have not been treated and, since these are on a cinder fill, considerable dust is raised when the planes are starting up, as can be seen from this view. To eliminate this there are a number of types that need only to be mentioned to engineers attending such a conference as this. There is, for instance, the light surface treatment.

With the use of tail-skids, the surface treatment is hardly deep enough except to lay the dust in sections of the field that are used only occasionally. Then there is the mixed-in-place type. With this type the local material is mixed on the field with an asphaltic binder to a depth of four or six inches. This type usually is much more satisfactory for airport work than the surface treatment. If a harder surface is desired, a local material can be brought in, laid to a depth sufficient to give a stable surface and then treated to prevent dust. However, such surface treatments are apt to be injured by action of the tail-skids with which many planes are now equipped. We are told, on the other hand, by the aviators and the airplane construction companies, that the future will soon see the complete elimination of the tail-skid. Heavier types of construction are now being built with success, such as the premixed type and the penetration type.

The field of the Kern County airport at Bakersfield, Cal., is composed of a sandy loam that has been treated with three-eighths of a gallon of 60 to 70 per cent asphalt. It is interesting to note that the pilots here reported an increased visibility for both night and day landing. That



W. E. ROSENGARTEN
TRAFFIC ENGINEER,
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may sound out of line with some of the arguments that have been raised, but I have heard it reported also from other airports that the dark surface readily is seen from above, especially during night landings and even without field lighting. That is true especially in sandy areas where the surrounding fields are white.

CONSTRUCTION AT PASADENA AND CHICAGO

At a Pasadena, Cal., airport, an oiled runway is in service. It is interesting to note here the absence of the dust usually kicked up by the tail-skid from a plane passing over the runway, whereas a plane else-

CURTISS AIRPORT, VALLEY STREAM, LONG ISLAND, N. Y.



BUILDING SAND-ASPHALT RUNWAYS BY THE MIXED-IN-PLACE METHOD—3¾ GALS. OF 80 PER CENT ASPHALT TO THE SQ. YD. SANDY SOIL. COST OF CONSTRUCTION, 70 CENTS PER SQ. YD.

where on the field raises some dust on the oiled surface. This, too, is illustrated in this view of the Pasadena airport. At Chicago, Ill., the municipal airport has cinder runways which have been oiled for the purpose of laying the dust.

JACKSONVILLE MIXED-IN-PLACE RUNWAY

At the Jacksonville, Fla., airport, a local material—shell—has been used to construct the foundation courses of the runways. These are about 6 in. thick. One-third of a gallon per square yard of asphalt has been applied, and on this has been spread a covering of cinders. At this same airport the mixed-in-place construction for the apron and the

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APPLYING 80 PER CENT ASPHALTIC OIL TO THE NATURAL SAND, OCTOBER, 1929

hangar floors has been used. The local sand has been mixed by harrows with successive treatments of asphalt. The view of the Jacksonville airport shows a plane on the runway and gives an idea of the character of surface.

LOS ANGELES, NEWARK AND VALLEY STREAM

Probably everyone has heard of the extensive development at the Grand Central Air Terminal near Los Angeles. The construction of the landing strip there is of particular interest. A few inches of additional gravel were brought in and, together with successive treatments of asphalt totaling 3.2 gallons per square yard, were mixed with local sand. In mixing this material, as many as forty and fifty trips back and forth with the graders were required in order to get a uniform distribution of the material. Following this, long-base drags leveled off the surface in order to eliminate waviness. The pavement was finished by a light rolling. This gave an excellent surface for landing. There is a considerable yardage of Warrenite Bitulithic asphalt paving along the runways and taxiways at this airport.

It was at the Curtiss Air Field, Valley Stream, L. I., that mixed-in-place construction was used for the first time in the East. No outside material was brought in, since the sand, when analyzed, showed a grading very close to that required for sheet asphalt. All that was necessary, on an area 600 ft. square which was designated as the landing and take-off section, was to spray successive applications of half a gallon of asphaltic oil, cut it into the sand with disc harrows and finally mix it back and

forth with tractors and blade graders until a uniform distribution was obtained. It was finished by rolling and the automobiles using the surface immediately after construction made no impression upon it. This construction was finished during the past summer.

At the Newark, N. J., airport, previously referred to, the aggregate most readily available for construction consisted of cinders. Therefore, two coats, each 4 in. in depth, were laid on the runway. Each coat of cinders was treated with cut-back asphalt so as to bind them together. The hangar floor at the Newark field also was treated in a similar manner, except that only one layer of 4 in. of cinders and the cut-back asphalt were used. The surface, after months of use, shows that the tail-skids make but very slight marks and have done no real damage.

CONSTRUCTION AT RENO AIRPORT

At the Central Airport, Camden, N. J., just across the river from Philadelphia, Pa., the penetration type of construction has been used. The foundation of the apron and also the foundations for two runways, each 1000 ft. in length, consisted of cinders. On that a 3-in. layer of slag was spread. This was penetrated in the usual manner with asphalt and a seal coat of cut-back asphalt and stone chips was applied in order to give a rough, well-bonded surface. It would seem that this penetration type of construction should find considerable use at airports, for it gives a dustless, all-weather and resilient surface at a comparatively low cost.

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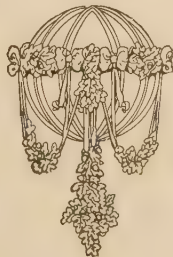
BUILDING MIXED-IN-PLACE SAND ASPHALT RUNWAYS. SHOWING HARROWING AND
BLADING OPERATIONS. ASPHALT WAS MIXED WITH THE SAND AT THE RATE OF 3%
GALS. PER SQ. YD. IN $\frac{1}{2}$ GAL. APPLICATIONS

CURTISS AIRPORT, VALLEY STREAM, LONG ISLAND, N. Y.

FINISHED SAND-ASPHALT RUNWAYS BUILT BY THE MIXED-IN-PLACE METHOD,
OCTOBER, 1929

At the airport near Reno, Nev., the asphaltic concrete, or "black base," construction was used for an apron $4\frac{1}{2}$ in. in depth. This airport is used by the air mail between New York and San Francisco. Mather Field, in California, uses 3 in. of asphaltic concrete which were laid on the apron as far back as 1918. • After 11 years of existence, this pavement is still giving service. It is interesting, too, to note that the marking paint used on the black surface for the message welcoming Col. Lindbergh remained clear and distinct for seven months, even though flood waters had swept over the surface. This view shows Col. Lindbergh's plane, the "Spirit of St. Louis," standing on this apron after the apron had been in service for ten years.

CHAIRMAN KENNEDY: If there is no further business, the meeting is adjourned.



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